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TEST & EVALUATION
of
'AWS: Hull Stress Monitor
on
C.C.G.S. 'PIERRE RADISSON'

Prepared for
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AUTHOR: A. Benjamin

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17. Abstract

Navigation of ships in ice currently relies heavily on the experience and judgement of the navigators. The NAWS System initiates a new concept in ice navigation. The objective is to provide the navigator with sufficient information to aid him/her to navigate icebreakers nearer the ship's optimum design specifications.

NAWS is a response monitoring system that obtains primary information from an array of strain gauges installed at high risk areas on the forebody structure of the ship. The locations of the gauges are determined using structural analysis supplemented by practical experience.

The sensor signals are processed by microprocessors and impact magnitude and location information displayed on a front panel on the navigating bridge. A printer keeps a permanent record of higher stresses.

A test and evaluation program for the NAWS system was conducted in summer 1983 on the CCGS Pierre Radisson while on escort duty in the high Arctic. The performance of the system was assessed through a computer controlled data recording system, and through responses from questionnaires and interviews with the captain and navigation officers of the ship.

Seventeen data tapes were recorded and analysed. Analysis of the crew's impressions show that the system achieved its principal objectives and generated gratifying enthusiasm onboard the ship. Recommendations for future systems have been documented.

The NAWS system remains in continuous operation for both summer and winter ice operations on the CCGS Pierre Radisson, providing an instantaneous risk assessment for navigators.

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17. Résumé

La navigation dans une mer chargée de glaces fait largement appel à l'expérience et au jugement de l'officier navigateur. Le système NAWS modifie la navigation dans les glaces, en mettant à la disposition de cet officier l'information lui permettant d'exploiter le navire au plus près de ses capacités nominales.

Il s'agit d'un système réactionnel qui tire ses informations d'un réseau extensométrique réparti sur l'avant du navire, là où la coque est fortement exposée. L'emplacement des extensomètres a été déterminé par une analyse de la structure, complétée d'une bonne dose d'expérience dans le domaine considéré.

Les signaux émis par les extensomètre sont traités par des micro-ordinateurs qui les convertit en information exploitable et les transmet au pont. Une imprimante fait le relevé des impacts significatifs.

Un programme d'essai et d'évaluation du système a été conduit durant l'été de 1983 à bord du Pierre-Radisson, alors en mission d'escorte à l'intérieur du cercle polaire. Les performances ont été évaluées à l'aide d'un enregistreur contrôlé par ordinateur, et grâce à des sondages par voie de questionnaires et d'interviews personnels auprès du commandant et des officiers navigateurs.

Dix-sept rubans ont été enregistrés et analysés. D'après les réponses obtenues des intéressés, le système aurait atteint l'objectif fixé, ayant suscité un accueil enthousiaste parmi les utilisateurs. Le rapport formule des recommandations concernant les applications nouvelles possibles de ce système.

Le système, toujours en service à bord du Pierre-Radisson, facilite grandement la tâche des officiers navigateurs appelés à piloter ce navire dans les glaces, été comme hiver.

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We appreciate the assistance and patience of the Captain, Officers and Crew of the CCGS Pierre Radisson who lent their expertise in evaluating the NAWS System, and demonstrated professionalism in carrying out this task.

Special thanks are due to Dr. Ruth Heron of TDC who designed the Evaluation Questionnaire and assisted in the ergonomic aspects of the NAWS System design.

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1.0 INTRODUCTION

Ships operating in the Canadian Arctic and involved in the icebreaking process are usually specially designed for this function. In most cases these ships have reinforced hulls to withstand impacts and are shaped differently from regular ships plying open water routes. The navigation of ships in ice is a specialized skill demanding precise judgement on the part of the ship's navigating officers who is referred to as an ice navigator. In addition to regular sea navigation duties, navigators must also familiarize themselves with these special ice navigation techniques.

The decisions involved in ice navigation include primarily the choice of the safest path through the ice and the selection of the maximum speed the ship may operate on this path without imposing undue stress (and the possibility of severe structural damage) on any section of the ship's structure.

Safe navigation requires the ship's officers to identify the type, age and thickness of ice in the ship's vicinity and assess its corresponding strength. Based on experience, the navigator then performs a mental correlation to determine the maximum speed the ship may operate without exceeding safe stress limits. He/she performs this estimation frequently, taking into account changes in the ice conditions. However, the only means of evaluation of the navigator's judgement is through indirect methods such as structural vibrations and the audio level of the impact.

In reality though, the navigator is not always able to obtain all information required in making this decision. Reasons vary from circumstances where poor visibility precludes proper identification of ice conditions, to practical considerations that require him/her to perform other functions in addition to navigating the ship through ice.

In addition, the navigator experienced with a certain class and size of icebreaking ship is not always able to transfer this expertise to another ship of a different size and structural strength. Hence, the decision of selecting the safe operating speed is subjective and a matter of judgement on the part of the navigator.

1.0 INTRODUCTION (Cont'd)

The optimum speed the ship operates at will be at or close to the highest speed the ship may operate without causing damage to any of the ship's structures or systems. While the more experienced navigators will operate close to this optimum speed, inevitably there will be some (although a small minority) who exceed safe limits endangering the ship's safety, while there will be others (possibly a larger number) that will operate somewhat below safe limits, thereby reducing the operational efficiency of the ship.

Hence, the need exists for a device that can provide the navigator an instantaneous evaluation of the ship's operating conditions. This direct feedback will enable him/her to take corrective action when necessary.

The new hull stress monitoring instrument developed by German & Milne Inc. under contract to Transportation Development Centre initiates a new concept in ice navigation. Its objective is to aid officers navigating icebreaking ships to operate nearer the ship's optimum design conditions. It is a response monitoring system that uses a microcomputer to analyze and interpret the severity of strains developed in the ship's hull structure during icebreaking.

The operating principle of a response monitoring system is shown in Figure 1.1. It provides information for the discretionary guidance of the navigators just as other modern electronic navigation systems supplement the traditional celestial, pilotage, and dead-reckoning forms of navigation. The system augments the officer's own sense of the traditional "feel of the ship" even as radar extends the range of his eyes and ears to detect obstacles to safe passage. By correlating the information reported by the system with his own intuition, the officer is aided in determining the optimum speed and course for the vessel. The device serves not only as an aid in avoiding damage to the hull structure, but also assists in the efficient operation of the ship.

A representative diagram of NAWS is shown in Figure 1.2.

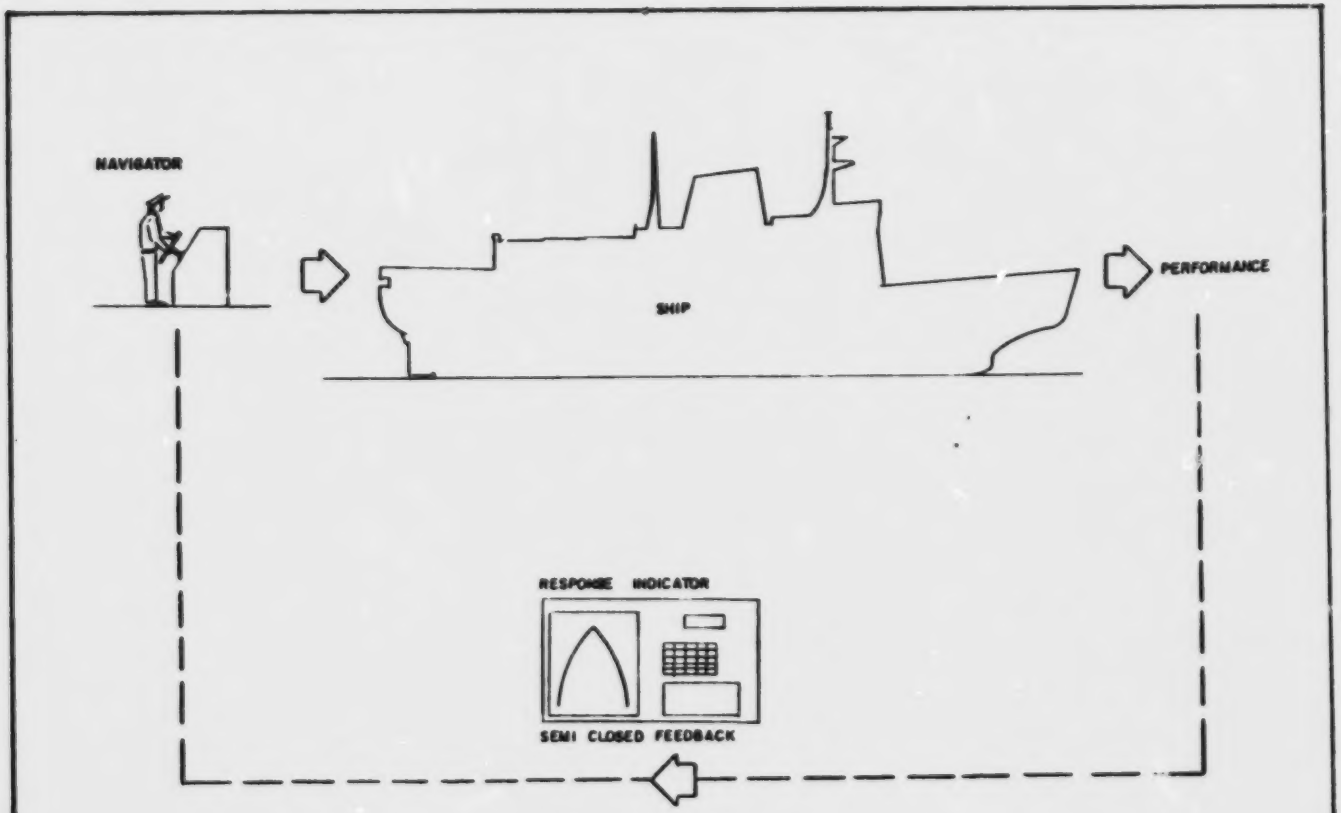

FIG. 1.1: RESPONSE MONITORING SYSTEM

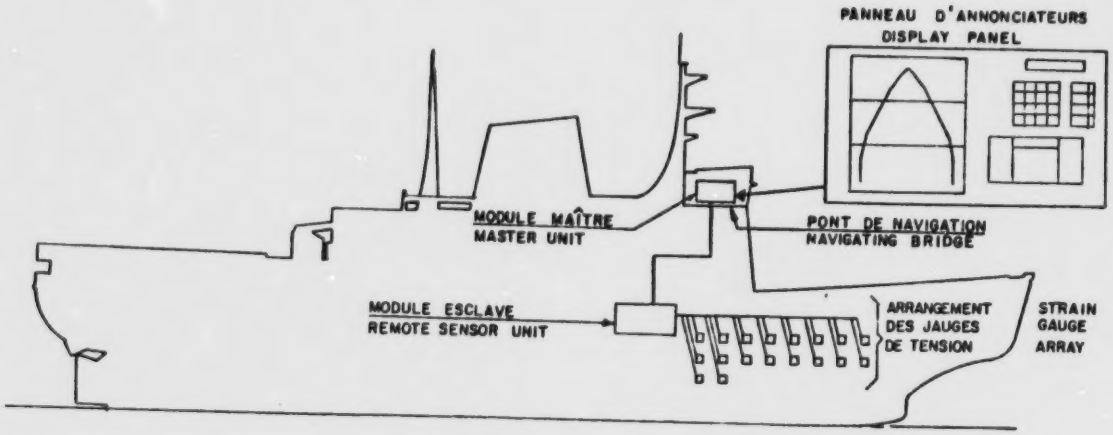

FIG. I.2-INSTALLATION TYPIQUE
DU SYSTÈME *NAWS*
TYPICAL *NAWS* INSTALLATION

1.0 INTRODUCTION (Cont'd)

The system uses strain gauges to measure stresses. A micro-computer is used to translate the measurements into information which can be used by ship's officers. This information is displayed on a front panel in the pilothouse.

The system obtains primary information from an array of sensors installed at strategic locations on the port and starboard bow areas of a ship. These sensors will provide signals proportional to the structural stresses caused by ice encounters. The system processes and interprets these signals into low, intermediate or high categories of stress levels.

The navigators are provided with a display of a sequence of lamp indicators that gives information on the general locations and intensity of encounters as they occur. Display of an encounter at high levels is accompanied by an audible signal.

A permanent record of all intermediate and high stress levels is made by a printer. The printout indicates the magnitude of the maximum stress, its structural location and the time of its occurrence.

2.0 SYSTEM DEVELOPMENT

The concept of a NAWS System came about through an unsolicited proposal to Transportation Development Centre (TDC) in April 1981. Since then, two generations of the NAWS Instrument (breadboard and pre-production models) have been designed, developed, tested and evaluated under contract to TDC.

The breadboard model was installed on the M.V. ARCTIC in June 1982 and used by the ship's crew during voyages to the Arctic that summer. Evaluation of the system by the ship's crew was obtained during one voyage to the Arctic on which German & Milne personnel were on board. Further comments on the system were received at the end of the season. These comments were instrumental in carrying out modifications to the breadboard model which resulted in the pre-production model.

This report describes the installation of the NAWS pre-production model on the CCGS PIERRE RADISSON as an operational instrument for Summer 1983, during which the ship provided escort duty in the Canadian Arctic. On two voyages to Eureka NWT, a German & Milne Inc. engineer was onboard as part of the Test and Evaluation program.

Evaluation of the System by the ship's crew was obtained through interviews and questionnaires and is documented later in this report.

Data monitored and displayed by the NAWS Instrument was recorded on tape with an HP-85 Computer. Analysis of recorded data and the results derived are also included in this report.

Finally, recommendations for future work and better implementation of the system in subsequent installations have been suggested.

3.0 ERGONOMIC CONSIDERATIONS

In designing the NAWS Response Monitor, human factor considerations played a significant role in determining the system's function in the ice navigation task.

On the one hand, if the system is sensitive and reliable, it will detect hull stress responses, the navigator cannot. The system monitors the hull/ice interaction and informs the navigator of the level of stress created by the response of the hull to the external conditions, but not the external conditions itself. It performs this task mechanically, yet efficiently; yielding information not otherwise available to the navigator.

On the other hand, the system is not a substitute for experience and judgement of the navigator, or for that matter, ice detection equipment. The system can provide the navigator with a lot more information to help him make a better decision: it cannot make the decision for him.

A navigator will accept the instrument only if he understands the meaning of the information received and knows how to use it to make decisions. He must also have confidence in its reliability and be able to incorporate monitoring of the new instrument easily into his regular tasks. It is, therefore, crucial that the navigator be able to easily relate the information received to the overall picture. Otherwise, he might be lulled by a false sense of security believing the instrument will detect all potential ice hazards, and his alertness would be reduced. Situations not sensed by the instruments would then take him by surprise. A properly designed instrument should provide information adjusted to the navigator's ability to interpret and act correctly.

In essence then, the NAWS System is not designed to substitute for experience and judgement of the navigator, but to serve as a supplement by providing information to augment his decision making capabilities.

4.0 SYSTEM DESCRIPTION

The NAWS System is designed to function as a forebody strain monitoring system while engaged in ice operations. It will monitor the strains in the hull structure caused by ice impacts and relay this information to the Bridge. A front panel display on the Bridge indicates when the strains exceed prescribed safe operating values, and an audio alarm sounds when they approach the yield point of the hull material. A permanent record of all unsafe strains is provided through a printer.

The System comprises of three units:

1. Strain Gauge Array
2. Remote Sensor Unit
3. Master Control

A block diagram of the NAWS System is shown in Figure 4.1. A description of each of the units follows:

4.1 Strain Gauge Array

The effectiveness of the hull stress monitoring system depends primarily on the strain gauge configuration. Therefore, it is necessary that much attention be given to the selection of location of the strain gauges.

The placement of the strain gauges was based on FEM analyses of the hull structure in way of the Bow Thruster Compartment and the Heeling Tank, and on Full Scale Trials Results from tests conducted on the CCGS PIERRE RADISSON in the Arctic in July/August 1978 and in the St. Lawrence River in February 1979. Both the above investigations were done as studies for the Canadian Coast Guard. A complete rationale for the placement of the strain gauges was submitted by GERMAN & MILNE to TDC in a separate document.

A total of thirty-two (32) gauges were installed on the forebody structure back upto the shoulder. The locations of the gauges on the starboard and port side are shown in Figures 4.2 and 4.3 respectively.

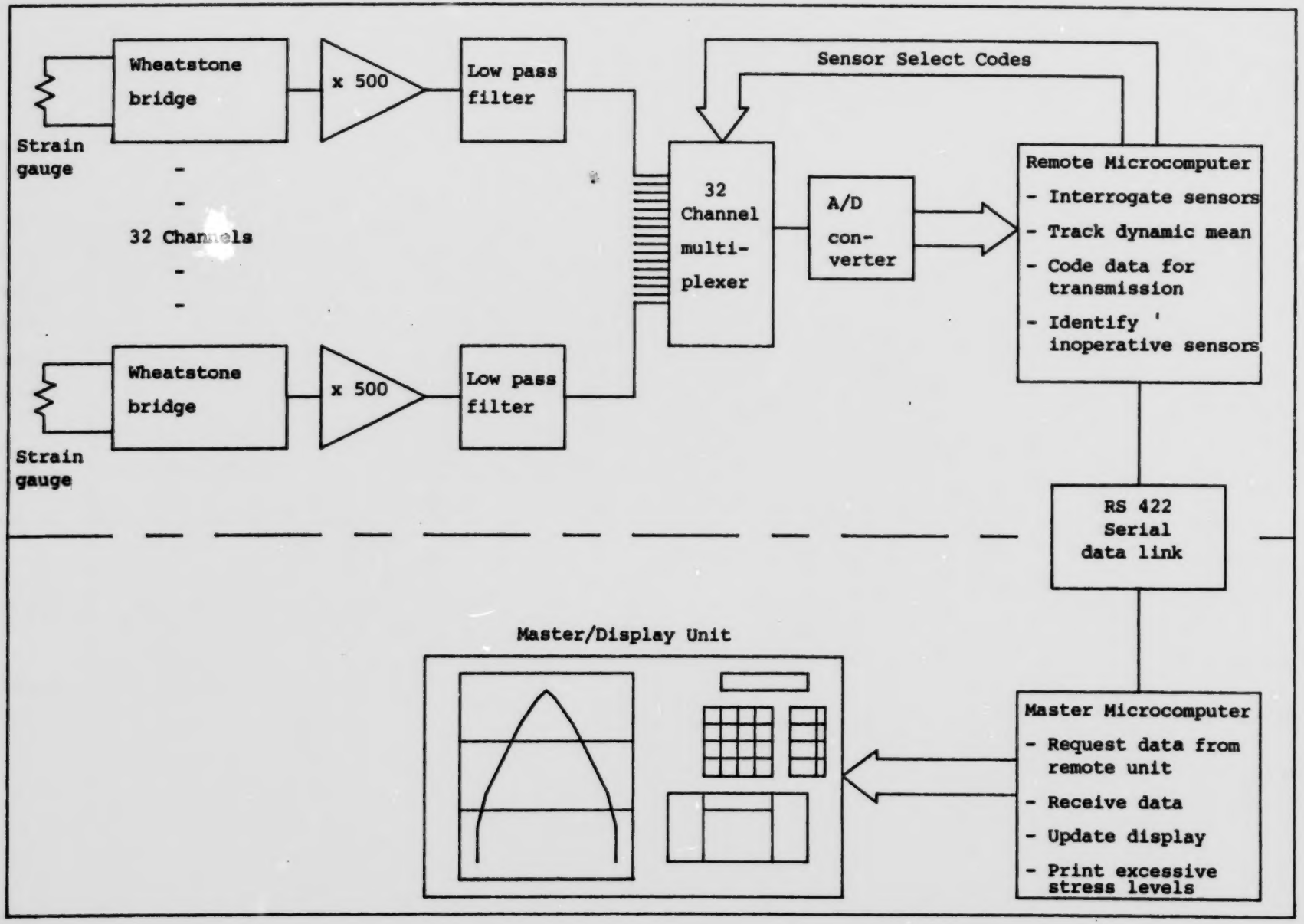

Figure 4.1: NAWS System Block Diagram

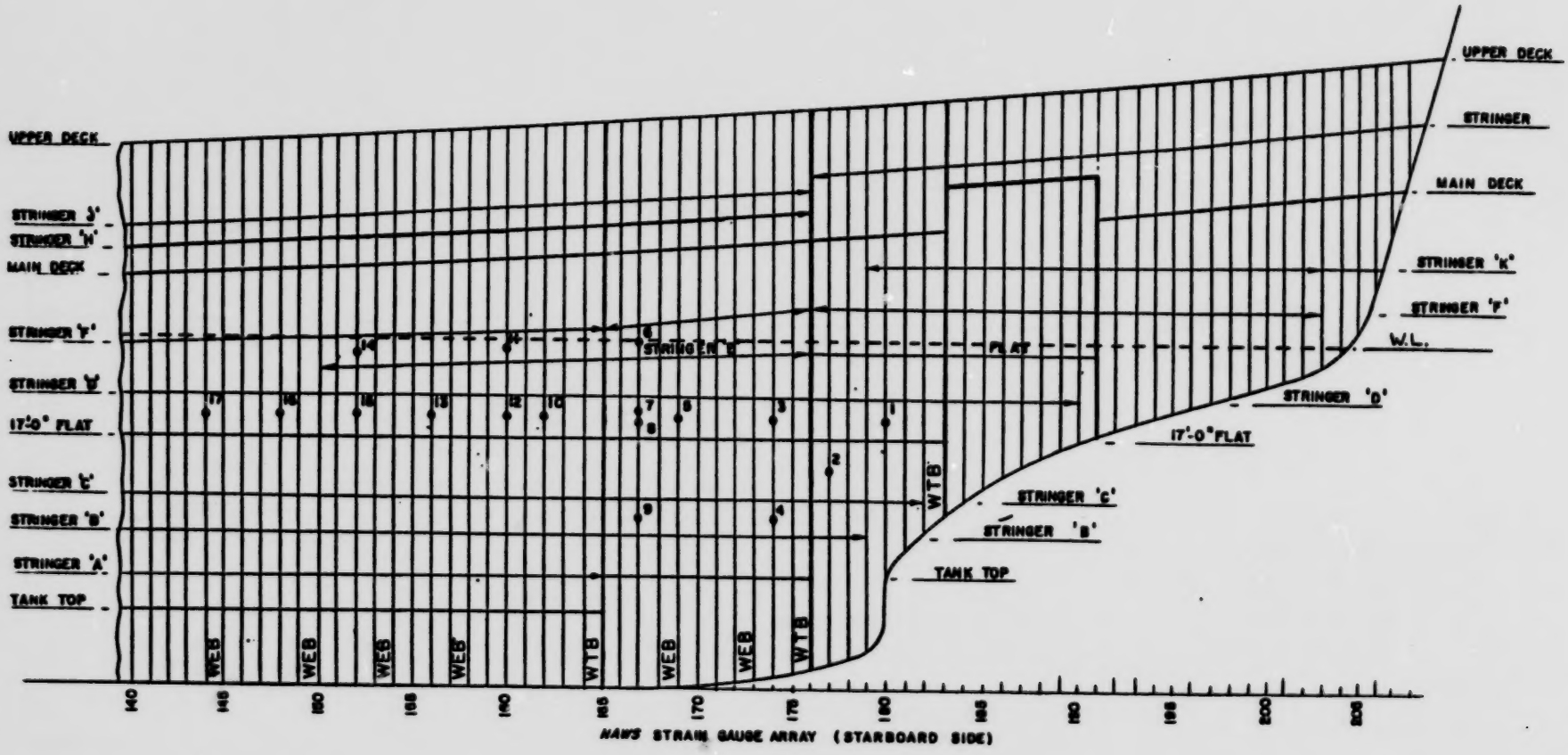

Figure 4.2: Starboard Gauge Locations

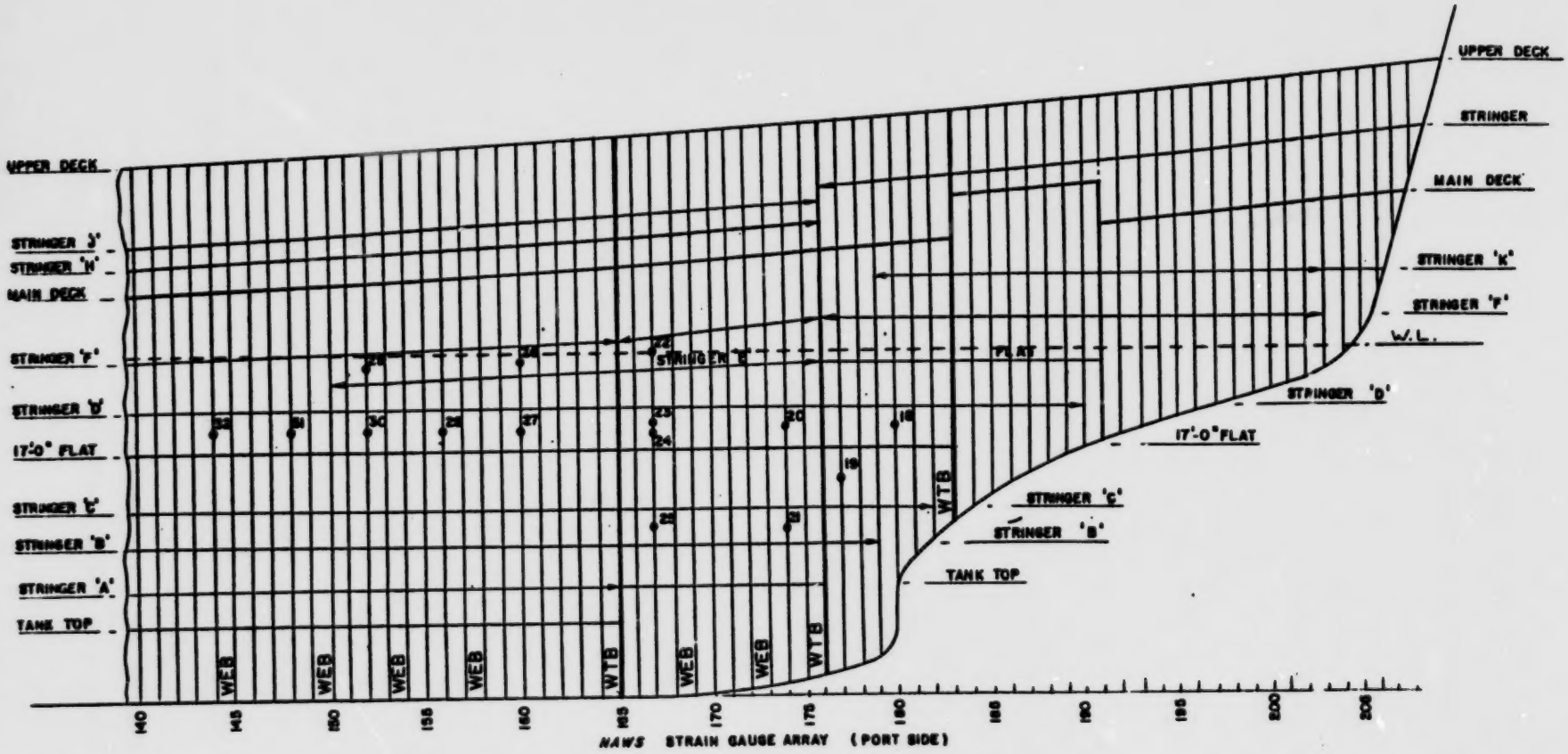

Figure 4.3: Port Gauge Locations

4.0 SYSTEM DESCRIPTION (Cont'd)

4.1 Strain Gauge Array (Cont'd)

Gauges are tested and calibrated at the manufacturer's plant and gauge factors provided for each strain gauge. The gain of each channel amplifier in the Remote Sensor Unit is adjusted to take into account the corresponding gauge factors.

4.2 Remote Sensor Unit

The Remote Sensor Unit obtains and processes basic data from the strain gauges. In turn, it transmits the information to the Master Control on the Navigating Bridge where it is displayed for the navigator.

Each strain gauge forms one arm of a Wheatstone Bridge, the output of which is fed to a high gain low drift instrumentation amplifier. The amplifier outputs a signal in the range of 0 to 10 volts, which is proportional to a range of $\pm$2000 microstrains being registered by the strain gauge. The amplified signal is then filtered prior to sampling in accordance with the Nyquist criterion. Filtering also removes any line frequency noise present.

A microcomputer controls all system functions. It samples each strain gauge sequentially. An analog multiplexer receives a sensor address and the corresponding output from an A/D converter is entered to the microcomputer.

The use of a microcomputer as the controlling unit gives the system considerable versatility. It can vary the number of channels which are handled, and routinely carries out computations and process information related to the strain gauge signals. Specific functions include:

1. Sample each strain gauge channel sequentially.
2. Keep track of any drift taking place in the strain gauges and amplifiers.
3. Compensate for residual strains in the ship's hull structure and the strain gauge itself.
4. Remove defective sensors from the sampling pattern in accordance with predetermined standards.

5. Monitor individual strains, compare with prescribed values, and provide a decision on whether the strain level being monitored is in the low, intermediate or high range.
6. Store the maximum strain encountered for each gauge until sampled.
7. Convey this information via a serial data link to the Master Control on the navigating bridge when required.

A sequential sampling pattern initiated by the microcomputer monitors all gauges at a fixed rate. The pattern is cyclic and is designed to sample at a minimum rate of 75 samples per second, per sensor.

For each strain gauge sampled, a dynamic mean value is retained by the microcomputer. The mean is computed from past samples using exponential averaging techniques. By comparing each sampled value with the current mean, the true reading of the strain encountered is determined. The current sample is then used to update the mean for use with the next sample.

An EIA RS422 serial data link conveys information from the microcomputer in the Remote Sensor Unit to the Master Control via an interface. The strain level for each strain gauge is fed sequentially to the transmitter of the Remote Sensor Unit. The data bus carries the signal through to a receiver at the Master Control located on the navigating bridge. Time-domain multiplexing techniques are employed. A parity bit is appended to each transmitted word for the detection of transmission errors, providing more reliable transfer of information.

4.3 Master Control

A micro computer within the Master Control co-ordinates all activities of the NAWS System. The Master Control samples each Remote Sensor Unit sequentially and sends the information received for display at the appropriate section of the front panel. The Master Control will also list bad sensors on the printer for the information of the operator.

4.3 Master Control (Cont'd)

The front panel provides a convenient means for the navigator to view stress levels. A sketch of the display is shown in Figure 4.4. On the left of the display a schematic diagram of the bow section of the ship consisting of an array of lights graphically arranged on an outline of the cross-section of the hull at the waterline. The coloured lights are yellow and red to indicate when stress levels are intermediate and high respectively.

When all stress levels are normal, the green indicator confirms system operation. The green LED at the centre marked stress is a bar graph display to aid the navigator to operate efficiently nearer the design specifications of the ship.

Each ice impact encountered that exceeds 50% yield stress illuminates the corresponding LED for a period of four seconds, irrespective of the actual duration of the stress. This helps to attract the attention of the operator.

The printer on the lower right hand side makes a permanent record of all intermediate and high level stresses (yellow and red alarms). The printout indicates the percent of yield stress encountered, its structural location and the time it occurred.

Additional features on the front panel include switches for the audio alarm and printer when not required and to reset the operation. The keyboard and display aid test, maintenance and other operations including an option for display of time as shown in Figure 4.4. However, if not required, the display can be blanked.

4.4 Microcomputer Hardware

Computer hardware for both the remote sensor unit and master control is designed around an INTEL 8085 microprocessor. In addition to inter-communication circuits, the master control has a real-time clock that is used by the printer to indicate the time of occurrence for each impact.

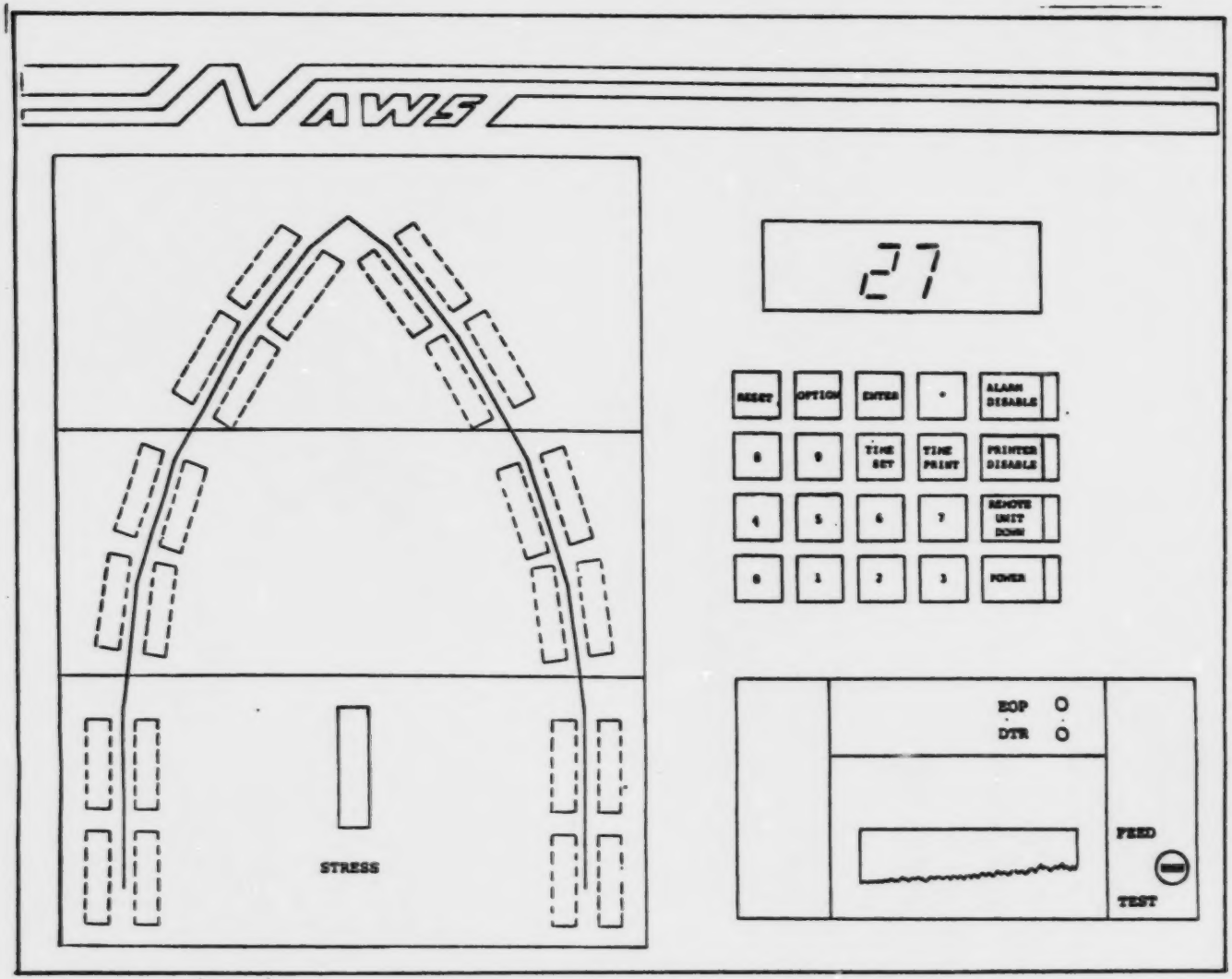

Figure 4.4: NAWS Front Panel Diagram

4.0 SYSTEM DESCRIPTION (Cont'd)

4.4 Microcomputer Hardware (Cont'd)

The use of a firmware - based system allows many special features to be incorporated in the system design. The number of sensors used can be modified at any time with a capability to up to 64 sensors per remote sensor unit. In addition, extra remote sensor units may be added up to a maximum of eight (8). Finally, it is also possible to update the system at minimal cost to accommodate downstream developments in the analyses techniques.

4.5 System Assembly

The packaging and construction of the unit is designed to be fully capable of long-term continuous operation within its working environment. All equipment is suited to an operating temperature range consistent with typical ambient conditions in its vicinity.

5.0 INSTALLATION

Installation of components of the pre-production model of the NAWS System was carried out in Quebec City between April and August 1983.

Based on the analysis of the ship's hull structure referred to in Section 4.1, the number and optimum locations for the mounting of the strain gauges were first determined. An array of thirty-two (32) strain gauges was considered to be sufficient to provide the required coverage for the NAWS System.

Since the strain gauge array is intended for long term use, and probable immersion under water, special consideration was necessary as to the type of gauge used. From both an environmental stand-point, and for ease of installation, past experience indicates that a weldable gauge with integral wiring is the most suitable. Consequently Ailtech weldable strain gauges type SG129 were selected for the application. However, to ensure reliable operation while immersed in salt water, a polyurethane coated grease block sheathed cable was used in place of the regular vinyl coated wire. These cables are hydro-tested for steel from -18°C to 82°C. All strain gauges had gauge-factors of 1.89.

Sub-contracts were awarded to Roctest Ltd., St. Lambert, for the welding of gauges and to Talbot Hunter, Quebec City for installation and cabling of the system.

Minor re-location of some strain gauges was necessary due to conditions encountered on board the ship which could not be foreseen during the planning stage. Following installation all gauges were tested for continuity, resistance and leakage to ground. Table 5.1 shows results of these tests: all gauges were considered satisfactorily installed.

Final integration of all system units and testing of the system was carried out by German & Milne engineers. The front panel and is location on the Navigating Console of the PIERRE RADISSON is shown in Figures 5.1 and 5.2.

TABLE 5.1: Strain Gauge Installation Tests

DATE: Week of July 11 to 14 1983 **SHIP:** Pierre Radisson

TECHNICIANS: Claude Bouchard/Gilles Dionne

Gauge No.	On Frame	Resistance (ohms)	Percent Deviation	Gauge Insulation Resistance
1	180A	120.9	.50%	
2	177A	120.6	.48%	
3	174	120.7	.58%	50 MEG.
4	174	120.3	.24%	50 MEG.
5	169	120.6	.48%	50 MEG.
6	167	120.6	.51%	60 MEG.
7	167	120.6	.51%	
8	167	120.9	.63%	50 MEG.
9	167	120.4	.34%	
10	162	121.0	.4%	
11	160	120.7	.5%	
12	160	120.7	.5%	40 MEG.
13	156	120.8	.42%	
14	152	120.6	.45%	50 MEG.
15	152	120.5	.4%	40 MEG.
16	148	120.5	.42%	
17	144	120.1	.10%	
18	180A	120.8	.55%	
19	177A	120.6	.51%	
20	174	120.3	.20%	
21	174	120.3	.3%	
22	167	120.6	.53%	
23	167	120.2	.12%	
24	167	120.4	.40%	
25	167	120.6	.48%	
26	160	120.4	.29%	
27	160	120.1	.12%	
28	156	120.6	.5%	
29	152	120.7	.47%	50 MEG.
30	152	120.3	.45%	50 MEG.
31	148	120.9	.48%	50 MEG.
32	144	120.6	.44%	

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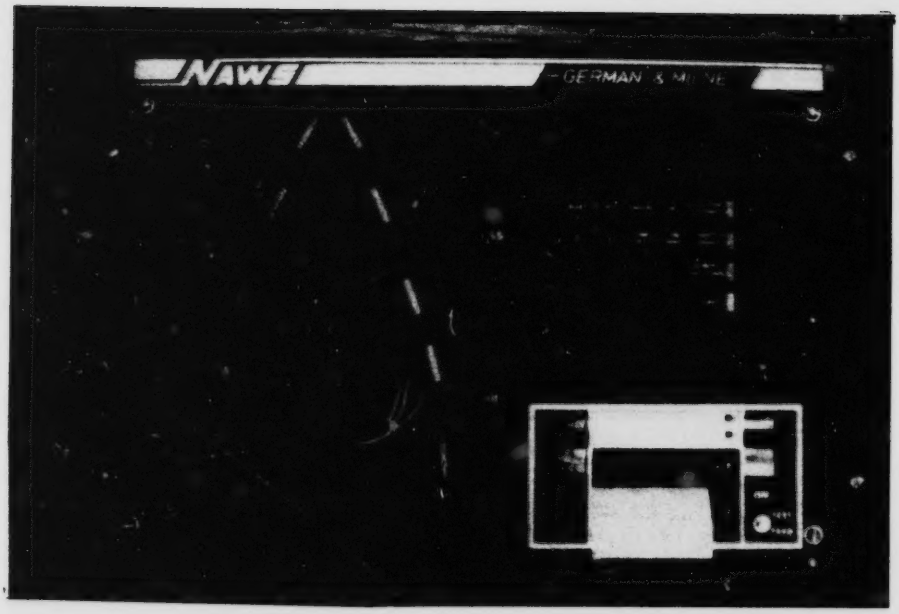

Figure 5.1: NAWS Front Panel

Figure 5.2: NAWS Installation on Navigating Console

6.0 TRAINING

To derive maximum benefit from operation of any instrument, proper training of the operators is essential. While the navigator can easily relate the information he gets from the instrument to the overall picture, it is necessary to make him aware of its limitations otherwise he might be lulled into a false sense of security believing the instrument will detect all potential ice hazards. His alertness would then be reduced, and situations not sensed by the instruments may take him by surprise.

Hence, based on our experience, the NAWS Instrument was carefully designed to provide information which we feel was adjusted to the navigator's ability to interpret and act correctly.

A Navigators Training Session for the Captain and Officers of the ship was held onboard the ship on 25th July 1983. The session included a brief description of the working of the system, and explanations of operations and controls. Some discussion of the information displayed in various configurations was carried out along with instructions for reset, time setting and changing of paper. An Operator's Manual and System's Manual were provided for further reference. As the crew of the ship are French speaking, the session was conducted in French. French versions of the manuals are also under preparation.

Electronics maintenance routines including simple trouble shooting methods were explained to the ship's Electrician officer on board the ship. Procedures for complete shut-down and start-up were provided.

7.0 TEST AND EVALUATION

7.1 Objectives

A special Test and Evaluation Program was conducted on the CCGS 'PIERRE RADISSON' in summer 1983, while on escort duty in the Arctic. During this period a German & Milne engineer was on board to monitor the system and assist the operators in use and interpretation of information provided by the system. Further the response of the crew to the system with their comments was solicited by the GERMAN & MILNE engineer through personal interviews and questionnaires.

The objectives of the Test and Evaluation Programs were as follows:

1. To determine the effectiveness of the Strain Gauge array as a sensing transducer.

   The final configuration of the array was arrived at using both a hull structural analysis and the available casualty analysis for the CCGS PIERRE RADISSON. Statistical analyses of recorded data (histogram, etc.) together with feedback from the navigator's, verified the sensitivity of the array, and assessed the suitability of each of the strain gauge locations.

2. To determine the suitability of the selected threshold levels.

   The choice of 50 percent and 80 percent of yield stress for yellow and red alarm thresholds respectively were chosen from operating levels recommended in the Lloyd's Shipping Regulations. Using these and a selection of different combinations, navigators evaluated the suitability of information for ice navigation and, where necessary, made appropriate recommendations.

3. To evaluate the ergonomic features of the information displayed on the front panel.

7.0 TEST AND EVALUATION (Cont'd)

7.1 Objectives (Cont'd)

While many considerations were taken into account in designing the NAWS front panel, possiblities for improving the efficiency of the transfer of stress related information to the navigator were investigated.

4. To develop software for a simulation of the NAWS front panel in different ice conditions during the voyage, using the recorded tapes.

This enables non-operating personnel in the Coast Guard, TDC and commercial marine industry to evaluate the front panel in different ice conditions. It can be used as a basis for training junior navigators in the use of the NAWS System.

7.2 Tools for Evaluation

Three tools were selected as a means to achieve the Test and Evaluation as discussed in the previous section:

1. Data Recording System
2. Questionnaires
3. Interviews

7.2.1 Data Recording System

A special data recording system was used to store on tape data being received and displayed by the NAWS System. The purpose of the Data Recording System was to review the data in light of comments on the system received from the crew and attempt simple correlations between the two.

7.0 TEST AND EVALUATION (Cont'd)

7.2.1 Data Recording System (Cont'd)

An HP-85 computer system was used as a data recording system for the duration of the evaluation program. It combines an alphanumeric keyboard, CRT screen, thermal printer, tape drive unit, user read/write memory, and a ROM operating system in one portable package, hence allowing ease of transportation on and off the ship.

A special interface was designed to handle data transfer between the NAWS Master Unit and the HP-85. The interface enabled the NAWS Instrument to communicate with other equipment with the syntax and formats of the ANSI/IEEE 488 standard. Handshake lines were used to coordinate the transfer of data over the data bus to ensure integrity of the data. The data transfer is asynchronous and the transfer rate automatically adjusts to the speed of the sender and receiver, ensuring that both devices are ready for the transfer operations.

The HP-85 data acquisition program is designed to request information from the NAWS system each time it is ready to store the data. Each data block transferred comprised 36 bytes of data. The first four bytes contained the date, hour, minute and second. The remaining 32 bytes were the maximum values encountered by each channel since the last data transfer. The maximum data transfer rate was one data block per second. The program had the flexibility to transfer information at slower rates. The rate was selected by the operator at the time of data recording. Recording rates as low as 1 data block per ten seconds were used when the ship encountered light ice conditions.

Results from data recorded by the HP-85 have been analysed in the next section (Section 8.0).

7.2.2 Questionnaires

A questionnaire was designed by Dr. Ruth Heron, Senior Ergonomist at TDS as a scientific means of obtaining the responses of the crew on all

aspects of the system. The use of a questionnaire provides a comprehensive means of evaluating the system in which the responder addresses all issues relevant to the system. In this way, the operator's views on minor details can be obtained, which is not always possible through an interview.

Responses to the questionnaires by the navigators were analysed by Dr. Heron and documented in a Special Report which has been included in Part II of this Report. It is believed that this independent assessment of the NAWS System enhances the objectivity of the system evaluation.

7.2.3 Interviews

Interviews were conducted by the German & Milne Engineer on different occasions during the voyage with the Captain and Navigating Officers. The purpose of the interviews was to supplement the questionnaires through discussion with the operators on improvements that could be made to the NAWS Concept. A summary of the interviews has been documented in Section 9 (Recommendations).

7.3 Schedule

The schedule of the ship during the Test & Evaluation Program was as follows:

Date	Time	Event
18th August '83	1700h	dep. Nanisivik
21st August '83	1130h	arr. Eureka
22nd August '83	1700h	dep. Eureka
30th August '83	0600h	arr. Pond Inlet
4th September '83	0130h	dep. Pond Inlet
6th September '83	2015h	arr. Eureka
8th September '83	0310h	dep. Eureka
10th September '83	1015h	arr. Grise Fjord

7.0 TEST AND EVALUATION (Cont'd)

7.3 Schedule (Cont'd)

Although a total of 18 days was spent on board ship, due to scheduling of the escort duty on the two voyages not all the time was spent in ice. In fact, during the period between the 25th of August 1983 and 4th September 1983, no significant ice was encountered.

7.4 Operations

It was intended that as many different types of ice conditions as possible would be recorded so as to get a large data base. However, ice conditions were sparse and hence recording of a sufficient number of different ice conditions necessary to provide the data base for a complete data analysis was not possible. As the CCGS 'PIERRE RADISSON, was providing escort service, it was not possible to deviate from the ship's course in the interest of safety of the escorted cargo ship.

The NAWS System was susceptible to Radio Frequency Interference (RFI) when messages were transmitted on the ship's radio. Tests conducted with the co-operation of the Radio Operator, showed that the serial link between the Remote and Master Units picks up the RF noise. This cable is routed very near the Radio Transmitters. Generally, when messages were transmitted all gauges showed red alarms and the numeric display indicated the maximum of 176% yield stress on all gauges. As the symptoms were distinct, it was not cause for confusion once the operating personnel were made aware of the problem.

The entire cable was replaced on return to Quebec City with Belden Datalene Cable 9184. This cable has 100% shield coverage and is also specially designed for precision computer and data communications applications. RF Tests were carried out using the ship's radio at different frequencies. No interference was detected and the system functioned properly throughout the radio transmission. It is recommended that this cable be used as the serial data bus in future installations.

We do not forsee any RFI problems on the NAWS installation. The system is currently in operation on icebreaking duty in the St. Lawrence River.

In order to provide a manual hardware reset to the system, an ON/OFF switch for the 5 volts supply (not in the original design) was installed on the front panel at Eureka (second trip) and labelled OUVERT. The switch allowed the operators to disable the front panel during radio transmissions.

Use of the above switch and information on the RF manual was provided to the operators as an addition to the operating manual.

One strain gauge (channel no. 32) was lost during the voyage on 26 August 1983 at around 1600 hours. Investigations on return of the ship to Quebec City indicate that the fault was caused by gauge failure and not by the cable. The channel was disconnected from the system which now functions with the remaining 31 gauges.

8.0 RESULTS OF DATA ANALYSIS

8.1 General

A total of 17 tapes was recorded on the two voyages to Eureka NWT. Details on the number of files recorded, date, start/stop time, elapsed time and the sampling interval for each tape is given in Table 8.1. A total of 131 hours of data was recorded on these two voyages.

Ice conditions varied considerably during these two voyages. The Operating and Environmental Recording Conditions are summarized in Table 8.2. The recording location, ship's draught and general ice conditions are given in the table. While the most severe conditions encountered in the recording of each tape are shown in the 'General Ice Conditions' column, much of the data was merely the monitoring of voyage conditions and was hence in light ice conditions.

In most cases, ice conditions were not consistent, hence no conclusive relationship could be established between the ship's operating parameters (ice cover/thickness, ship speed/mode, etc.). In fact, it was not the intent of the recording operation to achieve this, but rather to create a data base to determine the extent of strain gauge activity and consequently the NAWS front panel. This information is then correlated with the operator's comments to evaluate the ergonomic design.

All seventeen tapes were analyzed and histograms obtained for each tape. The results for Voyage 1 and 2 are summarized in Tables 8.3 and 8.4 respectively. The Impact Frequency Distribution of Voyage 1 is tabulated upto a maximum of 50% yield stress at intervals of 10% yield stress in Table 8.3. Since ice conditions (and stresses encountered) during Voyage 2 were not as heavy as in Voyage 1, its Impact Frequency Distribution is tabulated only upto a maximum of 35% yield stress at intervals of 5% in Table 8.4.

As is seen in Tables 8.3 and 8.4 stress values exceeding 50% yield stress (corresponding to yellow and red alarms on the system) are very infrequent. Thus, during the major portion of the time, the display of the NAWS System operates in the green region (low stress levels). The low number of alarms

Table 8.1

TAPES RECORDED

Tape No.	Number of Files Recorded	Date	Time Start	Time Stop	Recording Time	Sampling Interval
1	1	20th August 83	0437h	0548h	1h 11m	5 secs.
2	1	20th August 83	1451h	1630h	1h 39m	1 sec.
3	1	23rd August 83	0925h	1029h	1h 4m	1 sec.
4	1	23rd August 83	1848h	1951h	1h 3m	5 secs.
5	4	23rd/24th August 83	2032h	0100h	1h 57m	10 secs.
6	4	24th August 83	0144h	1628h	10h 22m	10 secs.
7	1	24th August 83	1638h	1816h	1h 38m	1 sec.
8	1	25th August 83	1351h	2318h	9h 27m	5 secs.
9	3	26th August 83	1105h	1619h	3h 40m	5 secs.
10	1	4/5th September 83	2328h	1058h	11h 30m	6 secs.
11	1	5th September 83	1110h	2058h	9h 48m	5 secs.
12	2	5/6th September 83	2131h	1157h	14h 26m	5/9 secs.
13	1	6/7th September 83	1208h	0518h	17h 10m	10 secs.
14	1	8th September 83	0953h	1946h	9h 53m	5 secs.
15	2	8/9th September 83	2023h	0844h	12h 21m	5/10 secs.
16	1	9th September 83	0949h	1931h	9h 42m	5 secs.
17	1	9/10th September 83	2005h	0953h	13h 39m	5 secs.

Note:

1. All times in EDST (Eastern Daylight Standard Time).
2. Channel No. 1 operational only from 1530h on 23rd August 1983 (file 4 onwards).
3. Channel No. 32 operational only upto 1530h on 26th August 1983 (upto file 9).

Table 8.2

SUMMARY OF SHIP OPERATING/ENVIRONMENTAL CONDITIONS

Tape No.	Location	Ship's Draught		General Ice Conditions
		Fwd	Aft	
1	Hell Gate/77°N 89°W	6.3m	7.6m	Upto 8/10 cover, 3m thick, MY pieces
2	Norwegian Bay/78°N 89°W	6.3m	7.6m	Upto 10/10 cover, 3m thick, MY pieces
3	Eureka Sound/78°N 87°W	6.6m	7.2m	Upto 4/10 cover, 2m thick, MY pieces
4	Norwegian Bay/Hell Gate/77°N 89°W	6.6m	7.2m	Light ice conditions, rotten ice
5	Jones Sound/76°N 88°W	6.6m	7.2m	Upto 10/10 cover, 3m thick, MY pieces
6	Jones Sound/76°N 85°W	6.6m	7.2m	Upto 10/10 cover, 3m thick, MY pieces
7	Lady Ann Strait/76°N 83°W	6.6m	7.2m	Upto 10/10 cover, 3m thick, MY pieces
8	Baffin Bay/74°N 82°W	6.6m	7.2m	Upto 7/10 cover, 1m thick, for MY pieces
9	Lancaster Sound/73°N 84°W	6.6m	7.2m	Upto 8/10 cover, 1m thick, open pack ice
10	Lady Ann Strait/Jones Sound/76°N 88°W	7.1m	7.2m	Upto 2/10 cover, 2m thick
11	Hell Gate/Norwegian Bay/77°N 89°W	7.1m	7.2m	Upto 9/10 cover, 3m thick
12	Norwegian Bay/Eureka Sound/78°N 87°W	7.1m	7.2m	Upto 6/10 cover, 2.5m thick
13	Eureka Sound/79°N 85°W	7.1m	7.2m	Brash first year ice
14	Eureka Sound/Norwegian Bay/79°N 85°W	7.1m	7.2m	Upto 10/10 cover, 2m thick, MY pieces, pressure
15	Norwegian Bay/78°N 88°W	7.1m	7.2m	Upto 9/10 cover, 3m thick, MY pieces
16	Hell Gate, Jones Sound/77°N 89°W	7.1m	7.2m	Upto 8/10 cover, 4m thick, MY pieces
17	Jones Sound/77°N 85°W	7.1m	7.2m	Upto 3/10 cover, 1.5m thick, MY pieces

Table 8.3

VOYAGE 1 - IMPACT FREQUENCY DISTRIBUTION

File No.	20	20 - 30	30 - 40	40 - 50	50
1	22,331	4	1	0	0
2	138,737	117	47	13	6
3	19,552	0	0	0	0
4	20,250	3	2	1	0
5	20,266	73	28	13	4
6	5,864	99	15	6	0
7	171,368	74	6	1	7
8	168,044	20	0	0	0
9	170,872	27	4	1	8

Table 8.4

VOYAGE 2 - IMPACT FREQUENCY DISTRIBUTION

File No.	20	20 - 25	25 - 30	30 - 35	35
10	171,261	3	0	0	0
11	166,882	43	2	8	9
12	172,481	22	2	5	2
13	162,368	63	0	0	1
14	168,496	31	5	4	8
15	175,863	64	7	10	8
16	170,543	36	0	4	9
17	82,786	19	2	4	5

simplifies use of the system by the navigator. Frequent yellow and red alarms would lead to desensititization of the navigators to the system and also require interpretation of the display. The infrequency of yellow and red lights enhances the probability that when they do occur they will receive the attention of the navigator.

It was observed that higher values of stress were experienced in the ramming mode than in the continuous mode. This is to be expected since for a particular ice environment, icebreakers resort to the ramming mode only when unable to proceed in the continuous mode. Discussion on information collected and results obtained in each of the two modes follow.

8.2 Ramming Mode

The most severe ice conditions encountered during the two voyages were on 20th August 1983 between 0130h and 0230h (approximately) at Hell Gate (77°N 89°W). At the time the ship was in consolidated pack ice (10/10 cover) of large multiyear floes, 3 metres thick with ridges upto 10 metres thick. The highest values of stress detected by each of the sensors is shown in Table 8.5. Ice impact information on the ramming mode from Table 8.5 is also depicted pictorially in Figure 8.1. Note that for consistency in the diagram information from channel no. 18 was duplicated for channel no. 1, as the latter was not recorded at the time. The NAWS printout obtained while operating in these ice conditions is shown in Figure 8.2. In this figure

01:56!PS-21!53%!

indicates that at 0156 hrs. an impact was detected on the Port Stern (PS) of magnitude 53% yield stress by Gauge No. 21.

Table 8.5

Maximum Stress Encountered on Voyages

Channel No.	Maximum Stress (% yield)	
	Ramming	Continuous
1	*	*
2	110%	45%
3	55%	52%
4	114%	34%
5	23%	29%
6	58%	35%
7	50%	45%
8	56%	47%
9	51%	31%
10	19%	34%
11	24%	24%
12	42%	34%
13	36%	57%
14	42%	34%
15	52%	67%
16	35%	57%
17	43%	31%
18	92%	35%
19	86%	65%
20	42%	60%
21	101%	45%
22	21%	29%
23	46%	35%
24	58%	43%
25	97%	34%
26	31%	23%
27	43%	52%
28	35%	43%
29	25%	31%
30	34%	32%
31	45%	25%
32	25%	23%

* Channel 1 was not monitored at the time.

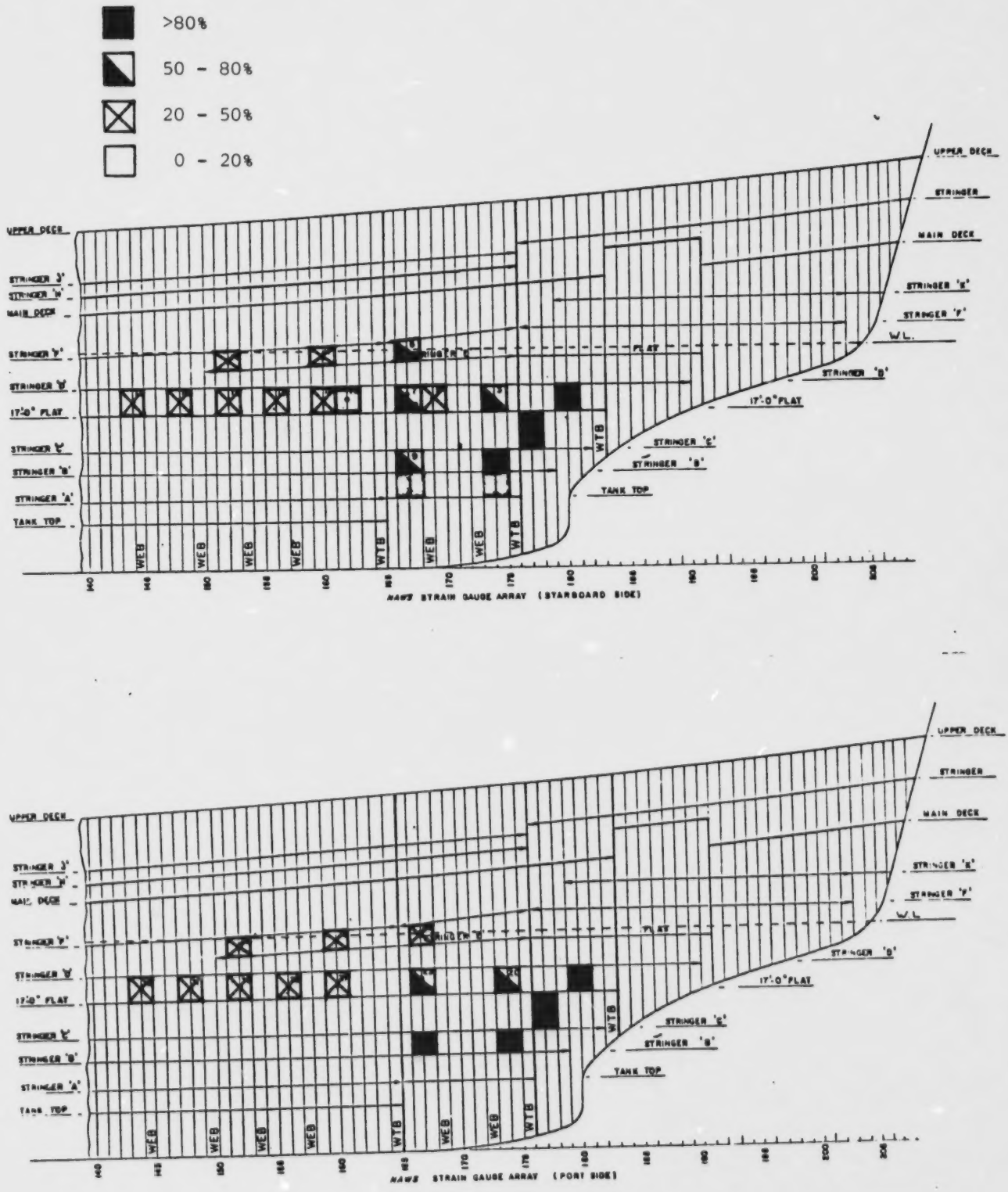

Figure 8.1: Maximum Stress Encountered in Ramming Mode

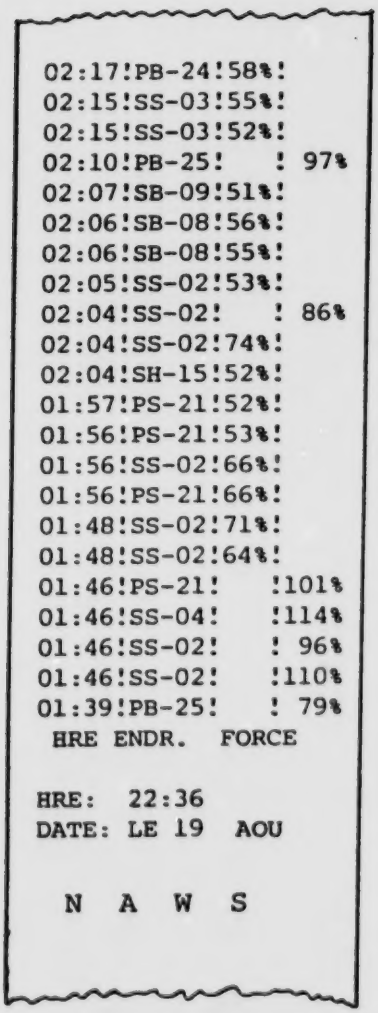

Figure 8.2: NAWS Printout in Ramming Mode

8.0 ANALYSES (Cont'd)

8.2. Ramming Mode (Cont'd)

Ice conditions were heavy and on one occasion (at 0146 hrs.) the bow of the ship was observed (by helicopter) to rise by 1.2 m. The Captain confirmed that, in general, the values registered on the printout corresponded to his own estimates.

As expected, the highest stress was encountered in the lower forward bow considerably below the water line. This is the area just aft of the Collision Bulkhead No. 183 back aft to Water Tight Bulkhead 165. In this region, Gauges Nos. 2 and 4 on the starboard side and 18, 19, 21 and 25 on the port side encountered the highest stress values (red alarms). Gauge No. 1 was not operational at the time. Almost all intermediate (yellow) stresses were encountered forward of Bulkhead 165 and hence it can be concluded that in the ramming mode the critical stresses will occur in the forward bow area. Except for Gauge No. 15, sensors aft of Bulkhead 165 did not experience any significant stress.

8.3 Continuous Mode

The heaviest ice conditions encountered while in the continuous mode were on 20th August 1983 between 1330 h. and 1600 h. (approximately) in Norwegian Bay (77°N 89°W). Very close pack ice (9 to 10/10 cover) 2 to 3 metres thick, with large multiyear floes was encountered at that time. Small ridges were also present, but did not necessitate ramming at any time. The highest values of stress detected by each of the sensors is shown in Table 8.5, along with maximum values detected in the ramming mode. The information is also depicted pictorially in Figure 8.3. For consistency in the diagram, information from channel no. 18 was used for channel no. 1, as the latter was not recorded at the time. The NAWS printout obtained while operating in these ice conditions is shown in Figure 8.4.

In comparison with Figure 8.2 it is observed that the magnitude of the stresses detected in the continuous mode are considerably lower than that in the ramming mode. Further, in this mode, higher stresses are predominantly

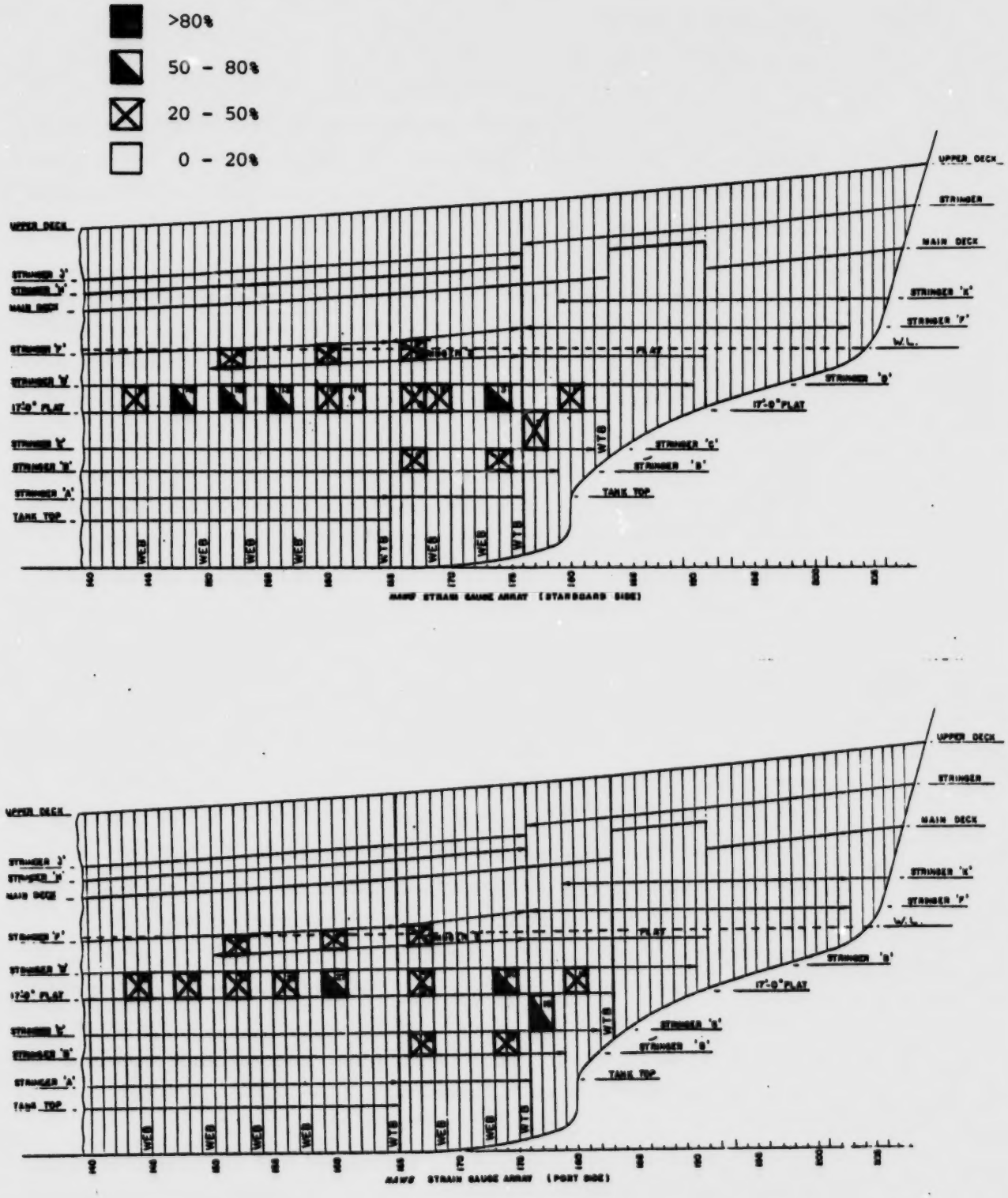

Figure 8.3: Maximum Stress Encountered in Continuous Mode

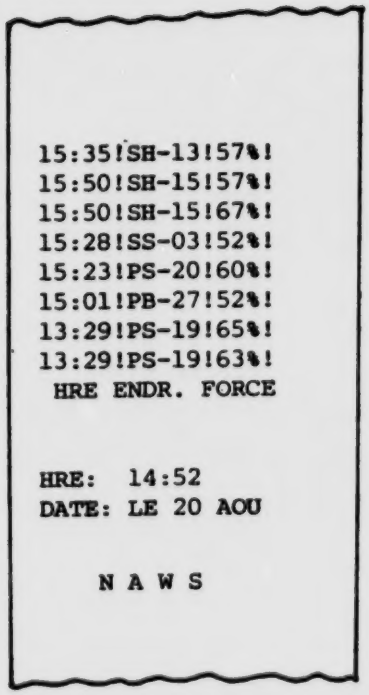

Figure 8.4: NAWS Printout in Continuous Mode

just below the water line, but unlike the ramming mode, reach back all the way to the shoulder.

8.4 Gauge Activity Level

Based on the above discussions and other data recorded, a Gauge Activity Table was compiled for the ramming and continuous modes.

Gauge activity levels are classified as high, medium and low in Table 8.6. Gauges have been grouped together where their locations on port and starboard side are identical.

Although Table 8.6 has been compiled from a limited data base (data from only two voyages) the Gauge Activity Level is representative of areas of the hull when probability of impacts is high. Further, it indicates that the choice of the strain gauge array was an adroit combination of two arrays designed to detect impacts in the ramming and continuous mode.

Table 8.6
Gauge Activity Level

Gauge Nos.	Ramming Mode	Continuous Mode
1-18	High	Low
2-19	High	Intermediate
3-20	Intermediate	Intermediate
4-21	High	Low
5	Low	Low
6-22	Intermediate	Low
7-8-23-24	Intermediate	Intermediate
9-25	High	Low
10	Low	Low
11-26	Low	Low
12-27	Low	Low
13-28	Low	Intermediate
14-29	Low	Low
15-30	Low	Intermediate
16-31	Low	Intermediate
17-32	Low	Low

Levels:	High	80% yield stress
	Intermediate	50% to 80% yield stress
	Low	50% yield stress

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9.0 RECOMMENDATIONS

Comments on the NAWS System performance were obtained by the German & Milne Engineer through personal interviews with the Captain and Navigating Officers.

The NAWS System generated gratifying enthusiasm from the Captain and Officers on the ship, and remains installed and in continuous use. In general, the system achieved its principal objectives, functioning as a tool to help navigating officers monitor hull stress in ice.

Some of the major recommendations of the navigators obtained in interviews are summarized below:

9.1 Location of Instrument

As a navigating device the location of the NAWS display aft on the navigation console (shown in figure 9.1) did not provide the navigator with instantaneous information on the stresses developed in the ship's hull as he spends the large majority of his time near the telegraph.

The device was located at this location because being unproven, the operators felt an evaluation of the usefulness and reliability of the system was called for. Further, location of the system aft on the bridge allowed the German & Milne operator continuous access to the system without interfering with the regular navigation duties of the ship's crew.

In this position, use of the system was limited to calling for the information by the navigator, from a NAWS observer. However, due to many aspects of the information provided (magnitude, colour code, location, etc.) not all information could be provided verbally. Many officers have indicated that having observed the device, they felt the usefulness of NAWS would be increased if located nearer the telegraph. Here, the device would give a direct instantaneous feedback of the ship's response to the navigator, thus helping in evaluating his decisions and consequently his ability to take corrective action when necessary.

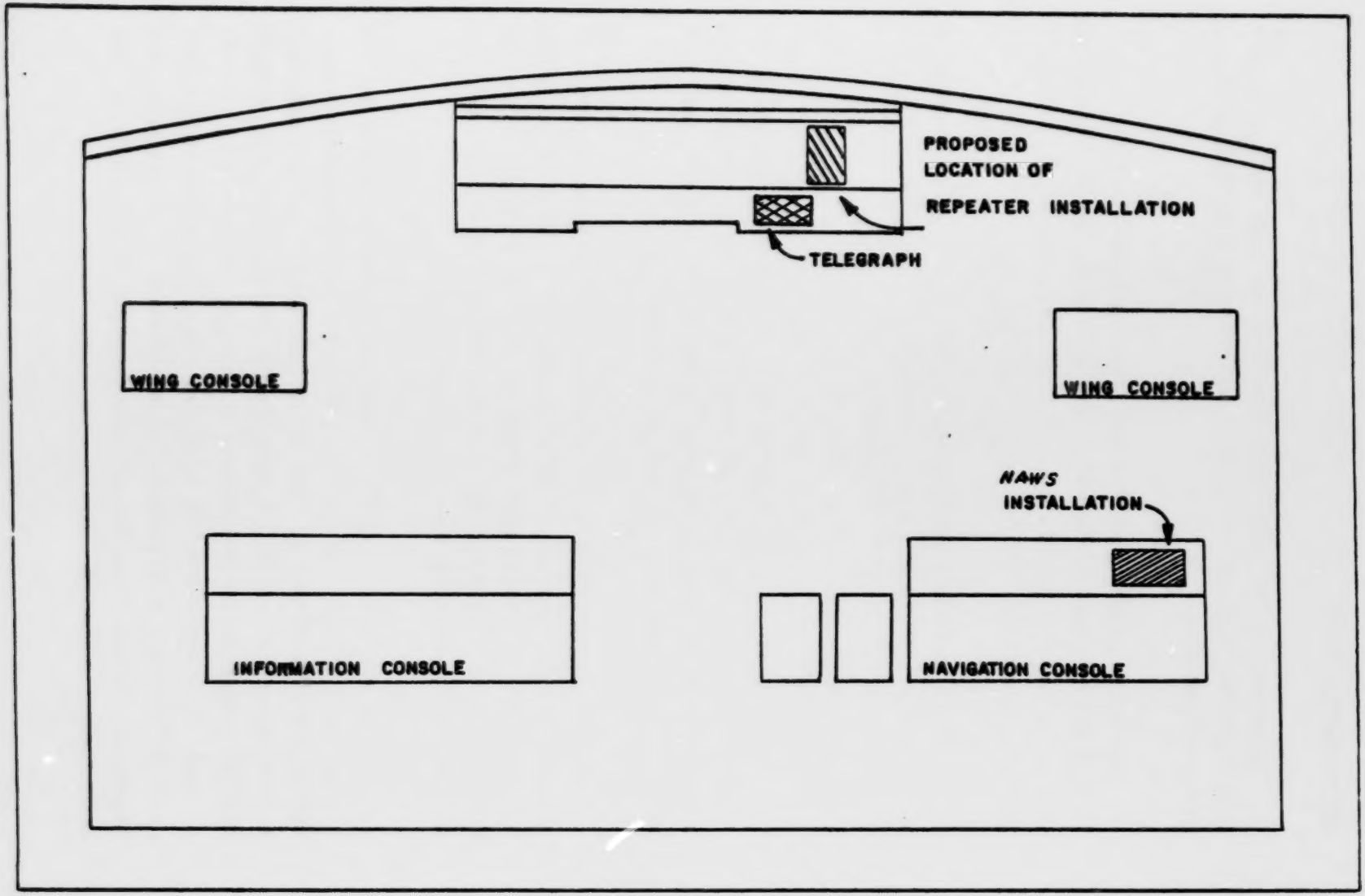

FIG. 9.1: WHEELHOUSE LOCATIONS OF THE *NAWS* SYSTEM & REPEATER

9.0 RECOMMENDATIONS (Cont'd)

9.2 Resolution of Higher Level Stresses

Display of the magnitude of the stresses has been colour coded into three levels:

Green:	Low level	0 to 50% of yield stress
Yellow:	Intermediate level	50 to 80% of yeld stress
Red:	High level	80% and above of yield stress

While stress indications at low (below 50%) levels are sub-divided into eight distinct steps (approximately 6% per step), no sub-divisions were used in the intermediate and high stress level indications (above 50%). Hence, when an intermediate or high stress level is observed, the navigator is not able to ascertain from the display whether the observed values are at the upper or lower end of the scale. It was suggested, therefore, that the principle used to display low stress levels be extended for use in displaying intermediate and high stress levels.

9.3 Display Retention Time

Indication of intermediate and high stress levels were retained on the display for three seconds. The general feeling here was that this gave insufficient time for the navigator to assimilate the information and make the next decision without having to memorize the information. A display retention time of 10 seconds was believed to be more appropriate.

9.4 Operator Controls

As a navigating device forward, it was recommended that dimmer and volume controls be made available for the lights and audio alarm respectively, so as to be kept below the visual and audio annoyance level.

9.0 RECOMMENDATIONS (Cont'd)

9.5 Alarm Threshold Levels

For the purposes of test and evaluation, the NAWS System had the software capability to modify the yellow and red alarm threshold levels. This would enable the operators to try out combinations of threshold values other than the default value of 50% and 80% yield stress. As discussed in Section 8.3, too much information (too many lights) leads to desensitization of the operator to alarms, while too few limits the usefulness of the system.

In general, the threshold values of 50% and 80% yield stress were considered well suited for the display and will be continued in subsequent NAWS installations. No option to modify alarm thresholds by the operator will be offered.

A sketch of one possible display for the repeater is shown in Figure 9.2. This new display format as envisaged by the Captain of the ship has incorporated the recommendations received during evaluation of the system. Consultations with the TDC Ergonomist confirms that from a human factors consideration the new format will be a more effective method of displaying the information. A proposed location for this installation is shown in Figure 9.1.

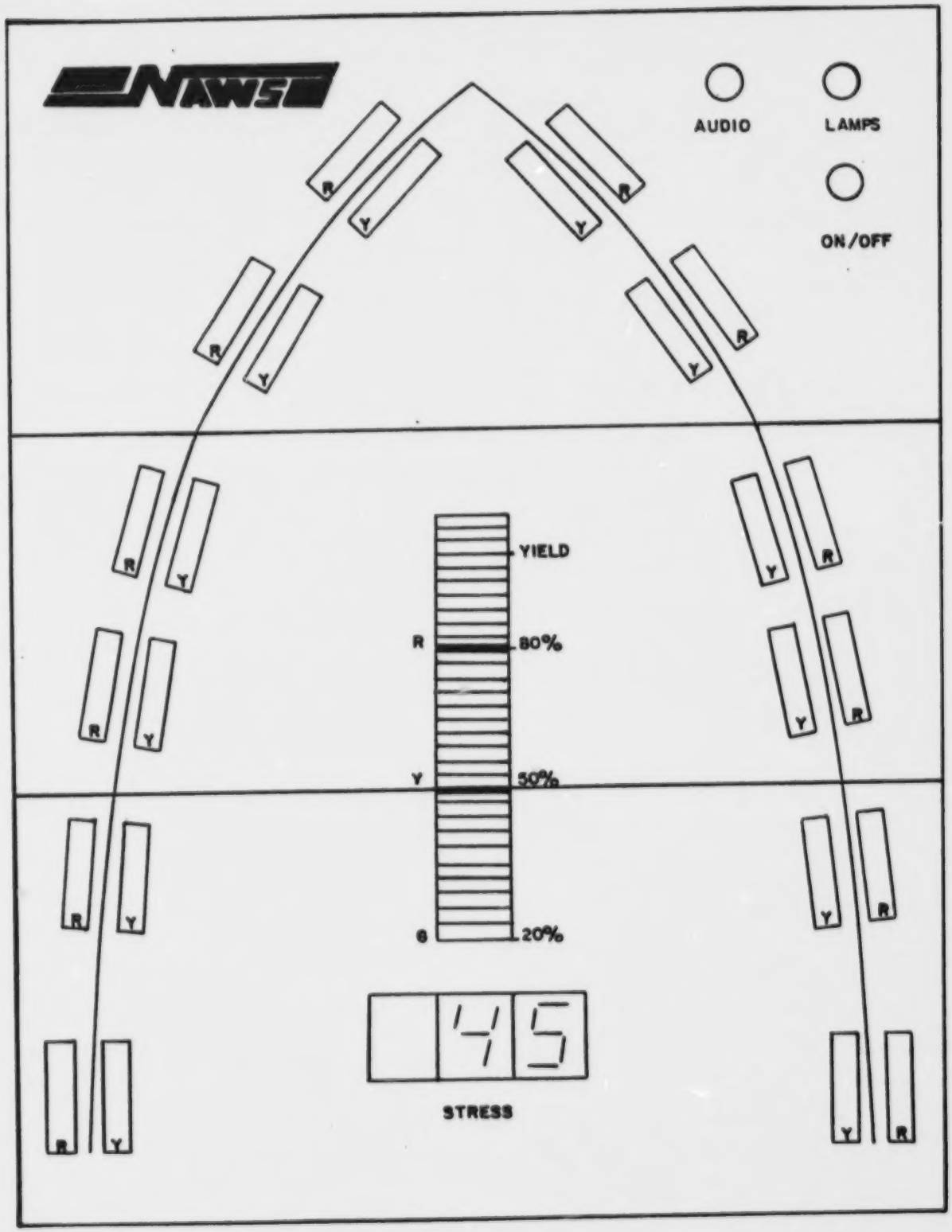

FIGURE 2. FRONT PANEL DISPLAY FOR REPEATER

10.0 FUTURE APPLICATIONS

While the primary function of the NAWS System is to monitor ice impacts on the ship's bow, the system can also be used to monitor other critical stresses caused by ice.

Ships navigating in ice fields experience high lateral pressure that may on occasion reach significant proportions. This situation is also encountered by ships frozen-in during the winter months. In both these cases, stress sensors installed amidships will monitor and warn the bridge of excessive field ice pressures.

In addition, during ice breaking the propeller and rudder equipment are also susceptible to damage by ice fragments. These too can be monitored by the system.

Further, the system concept can be extended to use in examining structural stress from encounters other than ice, which are often of equal concern.

A potential application here is slamming on ships where hydrodynamic loadings in heavy seas can cause damage to the scantlings and other areas of the hull girder. The impulsive loadings can cause whipping or springing of the hull, and vibrations at much higher frequencies than those usually caused by the passage of the waves. The stress cycling may cause fatigue problems, particularly at points of high stress concentrations as the rapid loading rates are more likely to cause cracking than are slowly varying hull bending stress. The NAWS System can be modified to monitor effects of slamming and fatigue on ship's structures.

Finally, the instrument is not limited to the use of strain gauges alone as the sensing element. Transducers such as accelerometers and thermistors may also be used in conjunction with the NAWS instrument to monitor forces and temperatures.

PART II

ERGONOMIC FIELD EVALUATION OF THE NAWS
Hull Stress Monitoring System

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1.0 INTRODUCTION

This paper describes and presents results of an ergonomic evaluation of the Navigation Aid Warning System (NAWS), carried out aboard the CCGS PIERRE RADISSON during its voyage from Nanasivik to Grise Fjord August 18 to September 10, 1983. The purpose of the evaluation was to try to pinpoint system design features which might be incompatible with sensory, perceptual, or task organization factors, with a view to recommending relevant modifications.

1.1 Evaluation Strategy

The strategy of the evaluation was importantly influenced by two facts: a) it had not been possible to carry out a systematic task analysis prior to development of NAWS, and b) it was not possible to apply direct observational and objective measurement techniques to the evaluation.

The absence of task analysis data meant that there were no precise preliminary details regarding i) the extent of strain gauge information needed or desired for navigation ii) the form in which such information would be most readily processed and used by the monitor and/or decision maker, or iii) the manner in which the new tasks of monitoring the device and utilizing its information would fit into existing navigational tasks. Hence the design of NAWS (fully described in the Feburary 1983 German & Milne Inc. report), and the decision to install it for the voyage in question on the ship's navigating console, could only be based on less comprehensive and precise information. Apart from this fact, the evaluation itself was forced into being longer, more convoluted, and less precise than it would have been with task analysis data available, necessary as it was to delve into matters more deeply in order to understand performance with the device. This problem was compounded by the lack of opportunity for direct observation and objective measurement, which then left open only the questionnaire method for obtaining insight into complex information-processing activities such as attention, detection, discrimination, recognition, transmission, and decision making (see Fitts & Posner, 1967; Welford, 1976). Hence the risk of omitting important considerations or misinterpreting results was added to the

1.0 INTRODUCTION (Cont'd)

1.1 Evaluation Strategy (Cont'd)

weaknesses of the questionnaire already mentioned. Nevertheless, it was considered that, given the co-operation of a number of ship's officers, sufficient information could be gained to ascertain the nature of any gross design modifications necessary.

Installation of NAWS on the ship's navigating console dictated that the task configuration for the evaluation be regarded as one in which the Captain received information from the device as relayed to him by another crew member having direct access to it. The resulting instrument, attached as Annex I, consists of three main sections: A, seeking general information regarding the respondent's position, years of experience, and frequency on watch during the voyage; B, containing probes regarding the signals and the task of monitoring them, and C, addressing the use of the information from NAWS in the navigation task. More specifically, items in Section B address i) perceptual properties of the green, yellow, and red lights and of the red light warning bell, ii) attention factors related to the monitoring of these signals, and iii) integration with previous task organization of the processes of monitoring the signals and of obtaining the printout. Section C attempts, in particular, to determine how information contained in the signals and printout might have affected navigational decision making. To ensure output of clarifying and other helpful information, a generous column for comments or suggestions was included on each page of the questionnaire. Moreover, instructions on the booklet cover urged respondents to make use of this column in a freely critical way.

2.0 METHOD

2.1 Respondents

Five respondents completed the instrument. Their respective years of navigation experience are summarized in Table I. As each respondent was associated with a different role in the organization of the crew, his experience with and use of NAWS was different. For example, the Captain

2.0 METHOD (Cont'd)

2.1 Respondents (Cont'd)

did some monitoring of the device but was mainly a receiver of its information as relayed to him by another monitoring officer. The First Officer and Second Officer were frequent monitors of NAWS; but as both alternated with the Captain in the command role, they were also frequent receivers of NAWS' relayed information. The Ice Observer received information directly from NAWS which he monitored for his own purpose

Table 1
Sample by Years of Navigation Experience

Respondent	Years of Experience	
	Icebreakers	Other Ships
Captain	30	2
First Officer	5	1
Second Officer	2.5	2
Ice Observer	19	-
Junior Officer	3	1

rather than that of navigating officers. The experience of the Junior Officer with the device was always as a monitor who relayed information to the officer in command.

2.2 Procedures

At the outset of the voyage, all relevant crew members were issued with a manual prepared by German & Milne Inc., explaining the operation and use of NAWS. Questionnaires were distributed by their Mr. A. Benjamin who explained the purpose of the evaluation and asked that any queries be referred to him. Booklets were completed towards the end of the voyage and returned to Mr. Benjamin. No attempt was made to prevent discussion among respondents of either the system or the evaluating instrument. It would have

been impossible to do so; in any case, as the aim of the undertaking was not to test hypotheses but rather to elicit information bearing on the design of the system, such discussion was seen as helpful rather than problematic.

3.0 RESULTS AND DISCUSSION

Responses are tabulated by item and respondent in Annex II attached. Results are summarized and discussed below under a number of selected headings.

3.1 Perceptual Properties of the System

Responses are consistent in indicating an absence of problems in detecting green, yellow, or red lights during night, daylight, or dawn/dusk conditions. Additionally, the stem, bow, and shoulder zones of the yellow and red signals, as well as their upper or lower positions within these zones, were reportedly readily discriminated. Thus no evidence was obtained suggesting that the brightness and size characteristics of the various lights are inadequate for any of the varying levels of illumination experienced in a fall arctic voyage. Moreover, the hull-shaped design of the display and its white crossbars are likely helpful in cueing observers regarding the relative positions of the yellow and red signals.

The evaluation produced no evidence to the effect that yellow lights are ever visually perceived as red, or vice versa. As many authors have pointed out (Coombs, Dawes, & Tversky, 1970; Fitts & Posner, 1967), discriminability of successive stimuli is increased (at a decreasing rate) when the competing stimuli are defined on more than one dimension. Thus it is possible that the respective outermost/innermost locations of the red and yellow signals add to their colour cues to enhance their ability to be distinguished. At the same time, although correspondingly located red and yellow lights are not seen simultaneously (in which case contrast effects would render them more discriminable, Bartley, 1969), they are nevertheless

located rather closely in space; therefore it is possible that, under certain conditions of ambient illumination, colour perception could be such that one member of a yellow/red pair could be mistaken for the other. A change in the shape of one of the coloured signals or, alternatively, increased visibility of the white line separating red and yellow pairs, is advised in order to reduce potential for this type of error.

Three respondents reported feeling that, on some yellow light events, the signal should have been red: for the Captain this experience was apparently frequent. In other words, other information (likely kinaesthetic) had indicated to these officers that, on the occasions in question, the impact to the ship was within the 80% to 100% range of yield stress rather than within the 50% to 79% range indicated by onset of the yellow light. It is the writer's understanding that the arrangement of some of the strain gauges in the ship's hull is such that a yellow light could be activated when stress to the ship was in fact >80%; hence it is possible that the respondents mentioned above were accurate in their perception that occasionally the yellow signal was under-representing the amount of stress incurred. If so, it is strongly recommended that light stimulus information be made to accord with both physical information (impact to the ship) and psychophysical information (kinaesthesis, or felt impact). The reason is straightforward. Ostry and Donderi (1983) have recently obtained data indicating that, without NAWS, a) perceptions of degrees of stress are being obtained through kinaesthetic effects arising from vibrations associated with the dynamics of the ship's motion in ice, and, b) navigating decisions are made on the basis of such proprioceptive feedback. These kinaesthetic cues will not disappear on introduction of NAWS. Hence, if they conflict with those obtained from NAWS' light signals, the confusion could affect decision-making. It should be understood also that, through feedback from the lights and the printout, the accuracy of the kinaesthetic perceptions of levels of stress can be improved over time. A first requisite for this process is that a given yellow light be clearly distinguishable from its red counterpart: but secondly, the degree of physical impact to the ship must accord with the signal and written record.

3.0 RESULTS AND DISCUSSION (Cont'd)

3.1 Perceptual Properties of the System (Cont'd)

It is only under these conditions that both visual and kinaesthetic input will be psychophysically concordant with ship hydrodynamics and, hence, that the hull stress monitoring system will be maximally efficient. Confusion and error may otherwise result.

Responses regarding properties of the warning bell, whose onset is simultaneous with that of a red light, indicate, first, disagreement regarding desirable pitch: while two respondents apparently feel the present pitch is adequate, two would prefer it to be higher, one lower. Additionally, three respondents expressed a need for a tone of higher intensity, all five a need for one of longer duration. The question of just exactly what physical properties the signal should have is difficult to treat since i) perception of sound is a complex function of frequency, intensity, and duration (Stevens & Davis (1938) and, in any case, ii) detection is dependent on the level of background noise in which a signal is presented (Green & Swets, 1966). Considering this latter fact alone, the lack of agreement regarding the tone's characteristics among the five respondents is not surprising; each observer was, after all, exposed to the signal during different periods of the voyage when ambient conditions were likely different. It is possible that sound emission from the printer, the onset of which is simultaneous with that of the tone, reduces audibility through the well known process of masking referred to by McCormick & Sanders (1982). Nevertheless, given that background noise conditions aboard ship will vary from time to time, a warning bell with an adjustable sound level is advisable. For a device whose function is solely predictive, this measure runs the risk of placing undue load on memory, because each time the monitor leaves the device to attend other tasks, he must ensure that the volume of the warning bell is turned up to a level audible from his new location. There are indications, however, that NAWS provides confirmatory rather than predictive information, in which case the consequences of not hearing the bell are lessened. If the bell is indeed to serve as a definite warning that some action needs to be taken, consideration should be given to presenting it intermittently to prevent adaptation (see McCormick & Sanders, 1982).

3.0 RESULTS AND DISCUSSION (Cont'd)

3.2 Use of Information from NAWS

3.2.1 Green Light Histogram

An attempt was made to determine whether monitoring officers tended to compress the 10 categories of the green light histogram into a smaller number. Unfortunately, imprecise responses were obtained in this respect, due likely to lack of clarity of the relevant questionnaire item. Still, the obtained data are sufficient to suggest that the 10 levels of the histogram do not correspond to 10 separable information needs. A decision on the number of levels to present should be made on the basis of how the information is going to be used as well as on how much the observer can easily process. In this respect, data from the study indicate, first, that green-light information was relayed to the officer in command only by the Junior Officer who did so only on some occasions. The explanation likely lies in the fact that the maximum level of the histogram represents only 50% yield stress and, therefore, a safe operating level; indeed, the colour coding, selected to accord with that of our present traffic light system, would carry with it learned associations of green = safe, yellow = caution, and red = dangerous. It is not surprising, then, that for the most part green-light information was not transmitted to the officer in command. If it were true that the histogram at maximum acted as a cue that a yellow light would shortly follow, monitoring officers may have been more inclined to report green-light information. However, questionnaire responses to items probing for attentional behaviour indicate that such was not the case. Instead, onset of green light at maximum tended to be followed by a lower level on the histogram because the first impact to the ship in an ice field is usually the strongest. On balance, then, if the present location of NAWS were to be maintained only one (or at most tow) levels of green would seem to be required.

However, notwithstanding the reaction of monitoring officers to the histogram, the Captain (the most experienced member of the crew) apparently considers that, if NAWS were directly accessible to him, the nature of green-light fluctuations would be extremely useful in making decisions regarding whether or not to increase speed. In this case, the

guiding principle is to present only that amount of information which can be comfortably processed, since more will serve only to overload processing capacity. In particular, it would likely be difficult to remember previous postions (other than the extreme ones) in a 10-level histogram. Miller (1956) has referred to the fact that capacity for an absolute judgment task is seven plus or minus two 'chunks' of information. On this basis, it is recommended that the existing 10 levels be comrpessed to seven (or to five if such would be more easily accommodated by prepared software). The existing design, vertical with moving (green light) indicator, is considered (Heglin, 1973; McCormick & Sanders, 1982) the most efficient for the purpose in question.

3.2.2 Yellow Light Information

Onset of a yellow light is meant to indicate stress to some specific area of the ship's hull within a range of 50% to 79% inclusive and, therefore, to signal an unsafe operating level. However, outcomes of the evaluation indicate that, as for the green light, stress levels associated with a yellow light were likely to be followed by lower ones, as the ship was automatically slowed up by the impact producing the yellow light signal. Briefly, then, the yellow light does not act as a warning of greater stress to come and, therefore, a signal to reduce speed, but rather as confirmation of stress already incurred and perceived through visual and kinaesthetic input. The First Officer's comments emphasize the after-the-fact nature of the signals and the erractic pattern of their sequential onsets, (e.g. from, say 15% to 55% and back again).

All monitoring officers (except the Ice Observer who monitored for his own purposes) reported transmitting yellow-light information to the officer in command. However, the form of these messages does not appear to have been consistent, possibly because some were read from the printer, others directly from the light display. The form of the message and the procedures for obtaining it must be based on the information required by the receiver of the information. If, on the one hand, exact percentages are not required, the

simplest form of message would contain only the location of the stress and the colour of the light - e.g. 'Starboard/Shoulder Yellow' (or 'Yellow Starboard/Shoulder' if extent of stress is more important than location). Such a form would require reference only to the light display (an arrangement which some responses indicate would profit by a longer duration of signal, possibly because sometimes the present 4-sec signal may disappear and its trace fade from memory before a completely formulated message can be transmitted).

Alternatively, if precise stress percentages were to be required, the monitor would need to read them from the printer. In this case, the light signals are not needed: apart from giving more precise information on degree of stress, the printout provides all of the remaining information contained in the lights and, according to questionnaire responses, its onset is an event which acts as an auditory cue to attend the device. To monitor the lights as well as the printer would only incur unnecessary information processing operations - for example, storing the light position information in memory and comparing it with that appearing on the printout. Given that information were to be relayed directly from the printer, its form should be standardized, e.g. 'Starboard/Shoulder 65%' (or again, '65% Starboard/Shoulder' if extent of stress is more important than location).

The discussion above assumes that NAWS is positioned such that the officer in command receives its messages as transmitted by another crew member. If the former has direct access to the device, its design will depend on whether he wishes to monitor only the lights, both lights and printer, or only the printer. The present configuration of NAWS would likely be suitable only if the second of these is true. If the last is the case, then again the lights become redundant; if it is the first (the apparent choice of the Captain for the voyage in question), then the printer component of the system might be separated from the module and placed elsewhere for others to monitor, since its onset sound may be distracting to the Captain and, in any case, it

may be inefficient or undesirable for others to move into his space in order to read it. Given that it is the lights the officer in command wishes to monitor, consideration might be given to increasing their duration. The Captain's responses indicate that he uses yellow- and red-light information to decide where he should make an inspection of the ice field; increased light duration would allow more time to store this information in memory.

3.2.3 Red Light and Warning Bell Information

Onset of a red light signals stress of 80% or greater at some site. The Junior Officer reported seeing a red light only three or four times during the PIERRE RADISSON's voyage, the First Officer and Second Officer almost never. However, the Captain reported seeing this signal frequently during ramming mode, this suggesting that an important use of the light system is to provide feedback as to how hard the hits are in such cases. Evidence from the study indicates that in other cases also, when the impacts were not deliberate, the function of the red light is confirmatory rather than predictive in nature, as was true for the yellow light. Messages regarding red-light information were the same in type of content as those for yellow-light information; and again their form varied from person to person, this pointing to a need for standardization.

Only the Junior Officer appears to have reacted to the bell warning signal. The sound of the printer, activated with onset of yellow or red light, was the cue for the First Officer to attend the system; the Second Officer reported relying on the ice field visuals for information regarding hardness of the ice, rather than reacting to the bell to direct him to NAWS. In sum, the utility of the bell as a cue to take some action can be questioned. Nevertheless, in time it may serve to aid in the discrimination of yellow and red signals, a process important for reasons discussed earlier. Meanwhile, the addition of volume control, already recommended, would leave use of the alarm system optional.

3.0 RESULTS AND DISCUSSION (Cont'd)

3.2.4 Computer Printout

The Ice Observer did not respond to the item regarding use of thecomputer printout; the Junior Officer reported that he did not refer to it, the Captain that he left this task to others. Responses of the First Officer and Second Officer suggest that the printout could be extremely useful as confirmation of officers' own estimations of impact, as a memory aid, and as a precise record of location and extent of stress.

The readability of the printout was judged 'very easy' by all but two respondents, both of whom judged it 'fairly easy'. There was an indication that greater contrast was needed. Actually, the light/dark contrast would seem to be difficult to improve upon; however spacing factors (McCormick & Sanders, 1982) may be reducing readability. For example, as Hull (1976) has demonstrated, strings of letters and numerals are better perceived when organized into small groups: for this reason, it would be advisable to eliminate the exclamation marks, as spaces would tend to define the groupings more clearly. Two spaces between groupings would bring about an even greater effect, one which could be realized if all percentages were printed in the same columns; those above 78% could then be marked with an asterisk. In addition, double spacing would facilitate reading of single lines by emphasizing figure/ground effects.

Apart from these considerations, some alterations to the form of the readout might be made in the interest of minimizing information processing operations. Apropos of this matter, the information of greatest importance (namely, either position or amount of impact) should appear leftmost on the paper strip. An example incorporating all suggested changes and assuming position of impact to be more important than extent, appears in Figure 1.

3.0 RESULTS AND DISCUSSION (Cont'd)

3.2.4 Computer Printout (Cont'd)

PB-24 28% 02:17
SS-03 55% 02:15

.....

SS-02 110% 01:46*
PB-25 79% 01:39*

HRE ENDR. FORCE

HRE: 22:36
DATE: 19 AOU 83
N A W S

FIGURE 1
Example of printout which may improve readability and reduce the reader's information-processing operations.

3.2.5 Task Organization

The Junior Officer indicated experiencing no difficulty in integrating the monitoring task into his previous task routine. However, responses of more senior officers (including the Captain) suggest that monitoring of NAWS from its location on the bridge was disadvantageous, and that installation should be such that the individual using the information (i.e. the officer in command of the ship) can obtain it directly. This arrangement would eliminate not only the task of relaying information from one crew member to another, but also the delay in receiving it. In addition, it would reduce transmission error, as well as over- or under-monitoring since the officer in command could then refer to the device only as he himself felt necessary. In sum, the location of NAWS for the voyage under consideration appears to have made for task inefficiency; therefore, its relocation as described above is strongly recommended.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The dynamics of ships navigating in ice conditions are such that stress to the ship is more inclined to be an erractic function over time than a steadily increasing one: typically, a high stress reading is followed by a lower one as a ship is slowed down by absorption of energy from a first impact. As NAWS produces evidence of these impacts after they occur, it cannot be regarded as a predictive device. Nevertheless, results of the present study suggest that it provides confirmatory evidence which can be useful in a number of ways.

For example, a consistent display of the green light below maximum could act as confirmation of the thinness of an ice field, and thereby, reduce uncertainty in a decision to increase speed. Onset of red or yellow signals could serve as useful input for decisions to alter speed during ramming mode or strategy during docking manoeuvres. In all cases the mechanism would be one whereby the NAWS signals would confirm or disconfirm the commanding officer's judgments and, thus, serve to reduce decision uncertainty.

A second use of NAWS derives from the fact that its signals occur simultaneously with kinaesthetic cues arising from the vessel's vibrations. Thus the former could provide the navigator with feedback that allows him (see Welford, 1976) to improve the accuracy of his kinaesthetically based judgments of stress. A more linear relationship between experienced and physical stress can surely only make for better navigation.

Apart from the foregoing, the printout from NAWS would appear to be useful for both documentation and planning purposes.

For the system to be maximally efficient in an ergonomic sense, some modifications appear to be necessary. Relevant recommendations are set out below under various headings:

1. Location of Module

   The present location of the module is associated with an inefficient organization of tasks. It should be relocated so as to allow the commanding officer direct access to it. This measure will i) eliminate

4.0 CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

1. Location of Module (Cont'd)

the information relay task, ii) reduce delay and error in transmission of information, and iii) confine the monitoring task to only that which is required by the receiver of the information.

2. Green Light Histogram

a) If the condition in 3 (a) holds, i.e. if precise information regarding stress levels >50% is needed, the yellow and red lights would become unnecessary; it would then make little sense to retain the green light histogram.

b) However, given the need for light information and taking into consideration the recommended relocation of the module, the number of green light categories should be reduced to, say, five in order to comfortably accommodate human capacity in an absolute judgment task, and to reduce memory load.

c) If the module were not relocated, the number of categories could be reduced to two; information from more than this number would be difficult to monitor and transmit.

3. Yellow and Red Lights

a) If precise information regarding stress is needed, it must be obtained from the printer; therefore, all lights could be discarded. Retaining lights under these conditions would tend to increase information-processing operations and create stimulus dazzle. All subsequent points assume the light information will be used.

b) Regardless of the location of the module, discriminability of the yellow and red lights in all ambient conditions of illumination should be ensured by intensifying the white line separating them. This is a first requisite for the conditioning mentioned in (c) following.

c) The yellow and red lights should accurately represent their designated ranges of physical impact. Otherwise they will provide incorrect feedback regarding accuracy of kinaesthetically based estimates and, thereby, block improvement in interpreting kinaesthetic cues and create confusion which may lead to decision errors.

4.0 CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

3. Yellow and Red Lights (Cont'd)

   d) The 4-sec duration of the yellow and red lights should be increased so as to reduce load on memory when attempting to i) relay a message, or ii) use the information to advantage in visual inspections of ice conditions after an impact.

4. Warning Bell

   a) As for the lights, the bell would likely not be of use if only precise information is to be transmitted or used, as the sound of the printer at onset acts as a cue to attend the module.

   b) If the bell is needed, it should have a volume control so that it can be adjusted to prevailing background noise conditions, or turned off entirely if necessary.

   c) An intermittent tone would likely reduce adaptation and, therefore, enhance detectability.

5. Printer and Printout

   a) Given the recommended relocation of NAWS and, further, that the officer in command makes use only of the lights, consideration should be given to separating the printer and light components and moving the former to a location away from the ship's commander. This arrangement would encourage free access to the printer by <u>other</u> officers and ensure that the sound of the printer does not interfere with the commanding officer's mental processes.

   b) To improve readability, the printout requires more spacing between groups of meaningful letters and digits, as well as between lines, (see Figure 1).

   c) To reduce scanning time and confusion during reading, the order of items should be changed to that shown in Figure 1, the most important being leftmost. (If amount of stress is more important than location of stress, the order of these items should be reversed.)

4.0 CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

6. Messages

a) Messages, whether read from the printout or from the lights, should be standardized in the simplest form with the more important part of the message preceding the less important. For example, if read from the lights and if position is more important than amount of stress, the message might be 'Starboard/Shoulder Yellow'. If read from the printer, a percentage figure would be substituted for the word 'yellow'.

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ANNEX I

NAWS Questionnaire

Name: _____

NAWS QUESTIONNAIRE

2. System Evaluation

The operation of the NAWS Hull Stress Monitoring System, installed on the bridge of the CCGS Pierre Radisson has been explained to you in the Operator's Manual and Instructions. To help evaluate the effectiveness of this device, your co-operation in completing the attached questionnaire is requested.

The questionnaire booklet consists of three sections:

A) Asking for general details of your experience.
B) Covering the monitoring process.
C) Dealing with the use of the information provided by NAWS.

In responding to the items, please feel free to be as critical as you wish, as it is only through the nature of your responses that an understanding can be gained of the kinds of modifications which may be necessary to optimize the system's efficiency. Any comments which will clarify our answers or any suggestions you may have for system design changes will be very welcome. A column to the right of each page is provided for this purpose.

THANK YOU FOR YOUR CO-OPERATION

***

A) GENERAL INFORMATION

1. Position on the Radisson _____

2. Years of experience

   on icebreakers ____
   on other ships ____

3. Did you monitor the NAWS this voyage? ____

4. No. times on this voyage in watchkeeping position ____

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS

B.1 Green Lights

a) In monitoring the green bar graph display, were you able to see the exact position of each of the 8 levels

	Yes	No	Reason
at night?	___	___	_____
in daylight?	___	___	_____
at dawn/dusk?	___	___	_____

b) Apart from the distinct visibility of the 8 lights did your eye tend to divide the graph into a smaller number of levels?

Yes No

c) If so, circle the number below at the place where your eye tended to make cutoffs.

1 2 3 4 5 6 7 8

d) When the bar graph reached the maximum (or near maximum) level, did you tend to keep your attention on the display for onset of one or more yellow lights?

Yes	Reason(s)	No	Reason(s)
___	_____	___	_____
	_____		_____
	_____		_____
	_____		_____

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS

B.1 Green Lights

e) If yes, did you find the delay of onset of yellow long?

Always Sometimes Never

f) How frequently did you relay information regarding the position of the green light to the Captain?

Never Sometimes Most of the time Always

B.2 Yellow Lights

a) In monitoring the yellow lights, were you always able to see clearly whether a light was on

	Yes	No
at night?	___	___
in daylight?	___	___
at dawn/dusk?	___	___

b) When a yellow light came on, were you always able to quickly recognize which zone it was in, stem, bow or shoulder?

Yes	No	Reason(s) if any
___	___	_____
		_____
		_____
		_____

c) Given that you could identify which zone a yellow light was lighting up in, could you always quickly recognize also whether the light was in the upper or lower position in that zone?

Yes	No	Reason(s) if any
___	___	_____
		_____
		_____
		_____

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS (Cont'd)
B.2 Yellow Lights (Cont'd)

d) How frequently did you relay information regarding the onset of a yellow light and its zone to the commanding officer?

Never Sometimes Most of the time Always

e) If applicable, please state the wording you used on these occasions.

_____
_____
_____
_____

f) Do you think the duration of a yellow light is long enough for you to be able to detect its presence on every occasion?

Yes No

g) With the onset of a yellow light, did you tend to keep your attention on the display for onset of the corresponding red light?

Yes	Reason(s)	No	Reason(s)
___	_____	___	_____
	_____		_____
	_____		_____
	_____		_____

h) Did you ever see a yellow light when you felt it should be red?

often sometimes never

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS (Cont'd)

B.3 Red Lights

a) In monitoring the red lights, were you always able to see clearly whether a red light was on?

	Yes	No
at night?	___	___
in daylight?	___	___
at dawn/dusk?	___	___

b) When a red light came on, could you always quickly recognize which zone it was in, stem, bow, or shoulder?

Yes	No	Reason(s)
___	___	_____
		_____
		_____
		_____

c) Given that you could identify which zone a red light was lighting up in, could you always also quickly recognize whether the light was in the upper or lower position in that zone?

Yes	No	Reason(s)
___	___	_____
		_____
		_____
		_____

d) Please state the wording you used on relaying information regarding the onset of a red light and its position to the officer in command.

_____

_____

_____

_____

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS (Cont'd)
B.3 Red Lights (Cont'd)

e) On a given 4-hr. watch, about how many times did you detect the presence of a red light?

_____

f) Of these, about how many detections were made as a sudden response to the bell alarm while you were engaged in another activity?

_____

g) Consider the adequacy of the bell as a signal for drawing your attention to the onset of a red light. In the table below, place a check mark ( ) in the appropriate cell that in your opinion, the characteristics the signal should have.

Duration		Duration of tone should be ____ sec.		Tone stays on until turned off by monitor	
Intensity	Character / Pitch	Steady	Intermittent	Steady	Intermittent
Greater	Higher				
	Same				
	Lower				
Same	Higher				
	Same				
	Lower				
Lower	Higher				
	Same				
	Lower				

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS (Cont'd)
B.3 Red Lights (Cont'd)

h) What proportion of the trip did you use the alarm disable? Explain why.

_____
_____
_____
_____

B.4 Use of Instrument

a) During a given 4-hr. watch, about how many times did you refer to the NAWS display?

_____

(b) About how many of these were routine checks made at regular intervals?

_____

c) Apart from the bell signalling the red light, what other circumstances (if any) caused you to refer to the NAWS display while you were engaged in another activity?

_____
_____
_____
_____

d) How readily were you able to incorporate monitoring of the NAWS display into the task routine which would have obtained <u>without</u> installation of NAWS?

_____	_____	_____	_____
with very great difficulty	**with a fair amount of difficulty**	**with a little difficulty**	**with no difficulty**

COMMENTS OR SUGGESTIONS

B) MONITORING PROCESS (Cont'd)
B.4 Use of Instrument (Cont'd)

e) Explain what the difficulties were, if any.

_____
_____
_____
_____

f) Explain your use of the printer option in a typical 4-hr. watch - i.e. the number of times and reasons for using the printer, reasons for shutting it off, etc.

_____
_____
_____
_____

g) Please use the space below to add anything which bears on how the design of the NAWS relates to the monitoring task.

_____
_____
_____
_____

C) USE OF INFORMATION FROM THE NAWS SYSTEM

1(a) On a typical 4-hr. watch in command of the Radisson, about how many times did you receive messages from another crew member regarding information obtained from the NAWS display?

_____

b) How many <u>types</u> of messages did you receive?

_____

COMMENTS OR SUGGESTIONS

C) USE OF INFORMATION FROM THE NAWS SYSTEM (Cont'd)

(c) For each <u>type</u> of message, please give below the approximate wording.

Type 1: _____

_____

Type 2: _____

_____

Type 3: _____

_____

(d) Now please complete the system evaluation table on the last page asking for information on how you used the various messages in your decision making with respect to avoiding stress to the ship's structure.

(e) Consider the total number of hull stress-avoiding critical incidents which occurred while you were in command of the Radisson on this voyage to date. Did you use a NAWS message to make a decision?

_____

2(a) During the total period that you have been in command on this voyage to date, how many times have you referred to the printout from NAWS for information?

_____

(b) Please explain below how you used this information.

_____

_____

_____

_____

COMMENTS OR SUGGESTIONS

C) USE OF INFORMATION FROM THE NAWS SYSTEM (Cont'd)

(c) How easy to read is the printout?

Very Difficult	Somewhat difficult	Fairly easy	Very easy

(d) If you did not check "Very Easy" in (c), please explain any problems in reading, even the most minor.

_____

_____

_____

_____

(e) What information, if any, would you like to see added?

_____

_____

_____

_____

(f) What information, if any, do you feel could be dropped?

_____

_____

_____

_____

NAWS QUESTIONNAIRE

2. System Evaluation

Message No.	Typical Critical Incident in which information from message was used to avoid stress to a ship	Decisions taken and relevant sequence of actions	List all the factors which contributed to each decision. Include the NAWS message listing each part separately of the message containing more than one factor	Rank the use in this column to add comments factors in which may assist in understanding only your use of the NAWS message importance in a given critical incident (1 is high)
1.				
2.				
3.				

ANNEX II

Excerpts from CCGS PIERRE RADISSON - NAWS Questionnaire

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

		Captain	First Officer	Second Officer	Junior Officer	Ice Observer
A)	Experience (years of service):					
	icebreakers	30	5	2.5	3	20
	other ships	2	0	2	1	0
	time on watch	Full Time	2 days	2 days	100 times	Daily
B)	Monitoring Process:					
1a)	night	MV	Y	Y	Y	NA
	daylight	Y	Y	Y	Y	Y
	dusk/dawn	Y	Y	Y	Y	Y
1b)		N	Y	Y	Y	(N)
1c)		NA	3	NA	8	
	Explanation to 1c) - Remarks:					
		NA	Green lights not not proportional to stress (3 = normal operation level - only 3 checked)	NA	MV	Lines should be clearer - higher intensity and thinner
1d)		N	Y	N	Y	Y
		Action instantaneous.	To check area.	First blow strongest. Therefore, yellow light on first or not at all.	Too fast.	
1e)		NA	Sometimes	Never	Never	Never
1f)		Most of the time	Never	Never	Sometimes	MV
2a)	night	MV	Y	Y	Y	Y
	daylight	Y	Y	Y	Y	Y
	dusk/dawn	Y	Y	Y	Y	Y

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

	Captain	First Officer	Second Officer	Junior Officer	Ice Observer
2b)	Y	Y	Y	Y	Y
Explanation to 2b) - Remarks	NA	NA	Ship's diagram on system is clear.		
2c)	(Y)	Y	Y	Y	Y
Explanation to 2c) - Remarks	With difficulty. Interested in how far back, sideways stress occurs.				
2d)	Always	Most of the time	Most of the time	Sometimes	MV
2e)	Captain asked AB frequently re: stress values, A = %	Zone and maximum stress from printer.	Yellow light, percent, zone.	No. and zone.	
2f)	(Y)	Y	Y	N	NA
Explanation to 2f) - Remarks	Increase to 8 seconds to permit analysis of type of ice encountered.	Don't need. Can refer to printer.		Increase to 6, 7 seconds.	
2g)	N	N	N	N	N
Explanation to 2g) - Remarks	Action instantaneous.	Either R or Y showed. Not R after Y.	Impact reduces speed, therefore stress less, and R does not go on.	Too fast.	Not unless there was subsequent impact.

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

		Captain	First Officer	Second Officer	Junior Officer	Ice Observer
2h)		Often	Never	Never	Sometimes	Sometimes
3a)	night	MV	Y	Y	Y	Y
	daylight	Y	Y	Y	Y	Y
	dusk/dawn	Y	Y	Y	Y	Y
3b)		Y	Y	Y	Y	Y
3c)		(Y) (See B, 2c)	Y Y	Y Y	Y Y	Y Y
3d)		MV	85% in port shoulder.	Red light, 95% zone.	No. and zone.	NA
3e)		Very frequently during ramming mode.	Almost never.	MV	3/4 times	MV
3f)		Not loud enough, needs adjustment.	Reacted to sound of printer, not bell.	Almost none. Ice field visual good indication of ice hardness.	2/3 times	MV
3g)		Same pitch, duration longer. Intensity greater.	1 second duration, steady, same pitch.	.5 second intermittent, lower pitch, (longer signal).	1 second higher pitch, higher intensity.	.5 second intermittent, lower pitch, greater intensity.
3h)		None.	Only when system malfunctioned.	50% of time, when adjustment not correct	None. No explanation.	Answer irrelevant - volume control most acceptable to users, would not be annoying.
4a)		Quite frequently.	Every time thought would hit hard.	10 times, near or in ice.	20/25 times	MV
4b)		MV	Never	Never	4/5 times	MV

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

	Captain	First Officer	Second Officer	Junior Officer	Ice Observer
4c)	During docking to confirm stress.	Only when thought would hit ice.	When ice in vicinity, seas heavy, panting.	Came mostly when heard alarm.	Ship about to contact significant floe.
4d)	No difficulty	MV	Fair amount of difficulty	No difficulty	MV
4e)	NA	Information interesting, but did not cause me to operate ship differently.	System on bridge a handicap. Should be used by person manoeuvring ship instantaneously.	NA	MV Should be at centre console on CCGB. A remote R and Y at each wing.
4f)	Frequently - always always a person watching NAWS.	In continual operation - showed record *instead of* precise range. Shut-off if not working.	Use as memory aid. Shut off in case *outside interference.* Printer skipped a step.	Did not use printer.	MV
4g)	Too far away to monitor. Should be close (in front of) telegraph. Histogram not needed if information immediate.	Not useful for continuous monitoring. Ideal for record of excessive impact.	MV	All is perfect.	Greater number of strain gauges would give more realistic reference to navigator.
C	Use of Information from the NAWS System:				
1a)	MV	Very rarely.	Never	NA	MV
1b)	1	1	NA	NA	MV
1c)	% stress.	% stress.	NA	NA	MV

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

	Captain	First Officer	Second Officer	Junior Officer	Ice Observer
1d)	Answer indicates that for a decision to send out dropper to survey ice, security was main factor, but does not indicate role NAWS might have played in influencing decisions.	Never used to avoid stress, ice impacts sudden, NAWS cannot predict. Steady increase in stress only after 50% then 80% reached. Therefore, NAWS not enough to influence decisions. After time, stress experiences might be relatable to ice thicknesses and forms. If getting red print-out each time hit hard, Capt. might slow or stop ship, but no such experience yet. NAWS excellent for record of stress.	MV	NA	MV
1e)	Information provided when low stress (indicated) ship capable of higher speed.	N	MV	NA	MV
2a)	Many times in several ice conditions.	Whenever printer activated.	MV	NA	MV

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

EXCERPTS FROM CCGS PIERRE RADISSON - NAWS QUESTIONNAIRE

	Captain	First Officer	Second Officer	Junior Officer	Ice Observer
2b)	To make decisions (when p/o 100/) i.e. stop, wait change on tides, find other path, proceed with care.	Not used to make decisions, but heavy stress situations limited. No correlations made on those occasions.	MV	NA	NA
2c)	Fairly easy (leaves to other officers).	Very easy	Very easy	Very easy	Fairly easy
2d)	NA	NA	NA		Print needs more colour intensity.
2e)	OK. Manual confusing too may cross references. Need summary card.	Information adequate as record of impact. Useful to retain high stress number for 10 seconds.	None	MV	Have stern monitored in same way.
2f)	OK	MV	None	MV	None.

NOTE: Y=Yes; N=No; MV=Missing Value; NA=Not Applicable. Brackets indicate a qualified response.

APPENDIX 'A'

Software Listings

```
 10 REM ** SIMUL **
 20 REM THIS PROGRAM SIMULATES
 30 REM  AS PER  RECORDED DATA
 40 OPTION BASE 1
 50 DIM X$[36],Q$[6]
 60 DISP "GERMAN & MILNE INC."
 70 DISP "NAWS SIMULATION"
 80 RESET 7
 90 SEND 21 ; UNL LISTEN 7
100 DISP "ENTER DATA FILE NAME"
110 INPUT Q$
120 CREATE Q$,850
130 ASSIGN# 1 TO Q$
150 DISP "SIMULATION BEGUN "
160 OUTPUT 7 ;X$
170 GOTO 140
180 ASSIGN# 1 TO *
190 END
```

```
 10 REM    ** NAWS1 **
 20 REM   THIS PROGRAM RECORDS
 30 REM   DATA ON TAPE AT THE
 40 REM   ASSIGNED RATE (DELAY) &
 50 REM   DISPLAYS THE SET NO
 60 OPTION BASE 1
 70 DIM X$[36],Q$[6]
 80 DISP "NAWS DATA RECORDING"
 90 DISP "--------------------"
100 DISP "GERMAN & MILNE INC."
110 RESET 7
120 SEND 7 ; UNL LISTEN 21
130 DISP "ENTER DATA FILE NAME"
140 INPUT Q$
141 DISP "ENTER DELAY PERIOD IN
    SECS"
142 INPUT K9
143 K9=K9*1000
150 CREATE Q$,850
160 ASSIGN# 1 TO Q$
170 DISP "RECORDING STARTED"
180 K=0
190 K=K+1
200 DISP K
210 ENTER 7 USING "#%,#%K,36A" ,
    X$
220 PRINT# 1 ; X$
230 WAIT K9
240 GOTO 190
250 ASSIGN# 1 TO *
260 END
```

```
  1 REM ** NAWS2 **
  2 REM READS TAPE & DISPLAYS
  3 REM ALL RAW DATA
 10 OPTION BASE 1
 20 DIM N$[256],X(36)
 30 DISP "NAWS 2 "
 40 ASSIGN# 1 TO "DATA1"
 50 K=0
 60 K=K+1
 70 DISP "Set# ";K
 80 READ# 1 ; N$
 90 FOR N=1 TO 4
100 X(37-N)=NUM(N$[N])
110 NEXT N
120 A1=X(36)/16
130 L1=IP(A1)
140 L2=RMD(X(36),16)
150 A2=X(35)/16
160 L3=IP(A2)
170 L4=RMD(X(35),16)
180 A3=X(34)/16
190 L5=IP(A3)
200 L6=RMD(X(34),16)
210 A4=X(33)/16
220 L7=IP(A4)
230 L8=RMD(X(33),16)
240 DISP USING 250 ; "Date:";L1,
    L2,"Time:",L3,L4,":",L5,L6,"
    :",L7,L8
250 IMAGE K,D,D,3X,K,D,D,K,D,D,K
    ,D,D
260 FOR N=1 TO 32
270 X(N)=NUM(N$[37-N])
280 IF X(N)>15 THEN 290 ELSE GOT
    O 320
290 X9=X(N)*1.3708
300 DISP USING 310 ; L1,L2,"d",L
    3,L4,":",L5,L6,":",L7,L8,"h
     ch#",N,X9,"%"
310 IMAGE D,D,K,4D,D,K,D,D,K,D,D
    ,K,DD,4D,K
320 NEXT N
330 DISP USING 340 ; X(1),X(2),X
    (3),X(4),X(5),X(6),X(7),X(8)
340 IMAGE 8(4D)
350 DISP USING 340 ; X(9),X(10),
    X(11),X(12),X(13),X(14),X(15
    ),X(16)
360 DISP USING 340 ; X(17),X(18)
    ,X(19),X(20),X(21),X(22),X(2
    3),X(24)
370 DISP USING 340 ; X(25),X(26)
    ,X(27),X(28),X(29),X(30),X(3
    1),X(32)
390 GOTO 60
400 END
```

```
  9 REM **  NAWS3  **
 10 OPTION BASE 1
 20 DIM N$[256],X(36),Q$[6]
 30 DISP "NAWS3"
120 CAT
130 DISP "ENTER FILENAME"
140 INPUT Q$
150 ASSIGN# 1 TO Q$
160 K=0
170 K=K+1
180 READ# 1 ; N$
190 FOR N=1 TO 4
200 X(37-N)=NUM(N$[N])
210 NEXT N
220 A1=X(36)/16
230 L1=IP(A1)
240 L2=RMD(X(36),16)
250 A2=X(35)/16
260 L3=IP(A2)
270 L4=RMD(X(35),16)
280 A3=X(34)/16
290 L5=IP(A3)
300 L6=RMD(X(34),16)
310 A4=X(33)/16
320 L7=IP(A4)
330 L8=RMD(X(33),16)
340 IMAGE K,D,D,3X,K,D,D,K,D,D,K
    ,D,D
350 FOR N=1 TO 32
360 X(N)=NUM(N$[37-N])
370 IF X(N)>30 THEN 380 ELSE GOT
    O 410
380 X9=X(N)*1.3703
390 PRINT USING 400 ; L1,L2,"d",
    L3,L4,":",L5,L6,":",L7,L8,"h
      ch#",N,X9,"%"
400 IMAGE D,D,K,4D,D,K,D,D,K,D,D
    ,K,DD,4D,K
410 NEXT N
420 IMAGE 8(4D)
430 GOTO 170
440 END
```

```
 10 REM  ** NAWS4 **
 20 REM THIS PROGRAM PRINTS DATA
 30 REM  ABOVE RECORDED LIMIT
 40 OPTION BASE 1
 50 DIM N$[256],X(32),Q$[6],D(4)
 60 DISP "** NAWS4 **"
 70 DISP "ENTER TAPE NO."
 80 INPUT N7
 90 PRINT "TAPE NO: ",N7
100 CAT
110 DISP "ENTER FILENAME"
120 INPUT Q$
130 PRINT Q$
140 ASSIGN# 1 TO Q$
150 DISP "ENTER THRESHOLD % :"
160 INPUT T1
170 PRINT USING 180 ; "Threshold
    =",T1,"%"
180 IMAGE K,4D,K
190 PRINT "-->-------------------
    ------------"
200 T1=T1/1.3703
210 K=1
220 B=0
230 READ# 1 ; N$
240 GOSUB 500
250 X0=0
260 GOSUB 580
270 GOTO 420
280 K=K+1
290 READ# 1 ; N$
300 GOSUB 500
310 X0=0
320 GOSUB 580
330 IF X0<9 THEN GOTO 390
340 IF B<>0 THEN GOTO 480
350 PRINT USING 360 ; D(1),"d",D
    (2),":",D(3),":",D(4),"  *.
    "
360 IMAGE 2D,K,5D,K,2D,K,2D,K
370 B=1
380 GOTO 480
390 IF B=0 THEN GOTO 420
400 PRINT USING 360 ; D(1),"d",D
    (2),":",D(3),":",D(4),"
    ...*"
410 B=0
420 FOR N=1 TO 32
430 IF X(N)>T1 THEN 440 ELSE GOT
    O 470
440 X9=X(N)*1.3703
450 PRINT USING 460 ; D(1),"d",D
    (2),":",D(3),":",D(4),"h  ch
    #",N,X9,"%"
460 IMAGE 2D,K,3X,2Z,K, 2Z,K, 2Z
    ,K,DD,4D,K
470 NEXT N
480 GOTO 280
490 END
500 REM *SUB READS DATE *
510 FOR N1=1 TO 4
520 X1=NUM(N$[N1])
530 L1=X1\16
540 L2=X1 MOD 16
550 D(N1)=10*L1+L2
560 NEXT N1
570 RETURN
580 REM *SUB READS DATA*
590 FOR N=1 TO 32
600 X(N)=NUM(N$[37-N])
610 IF X(N)>15 THEN X0=X0+1
620 NEXT N
630 RETURN
```

```
  9 REM  ***********
 10 REM  ** INDEX **
 11 REM  ***********
 20 REM THIS PROGRAM READS  DATA
 30 REM  & FORMS HISTOGRAMS  **
 40 OPTION BASE 1
 50 DIM N$[256],X(32),Q$[6],D(4)
    ,H(33),R(33)
 60 DISP "** INDEX **"
 70 DISP "ENTER TAPE NO."
 80 INPUT N7
 90 PRINT USING 91 ; "TAPE NO.",
    N7
 91 IMAGE K,5D
100 CAT
110 DISP "ENTER FILENAME"
120 INPUT Q$
130 PRINT Q$
140 ASSIGN# 1 TO Q$
160 DISP "ENTER THRESHOLD % :"
170 INPUT T1
180 PRINT USING 190 ; "Threshold
          =",T1,"%"
190 IMAGE K,      4D,K
200 T1=T1/1.3703
220 PRINT "--------------------
    -----------"
230 K=0 ! counts records
240 B=0 ! true when rt intef
250 FOR N1=1 TO 33
270 H(N1)=0
271 R(N1)=0
290 NEXT N1
300 READ# 1 ; N$
310 GOSUB 880
320 DISP USING 330 ; "Tape Start
     Date=",D(1),"d   ",D(2),":"
    ,D(3),":",D(4)," h"
330 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
340 DISP "Start Here ?"
350 INPUT R$
360 IF R$="Y" THEN GOTO 421
370 DISP "ENTER START DATE/TIME"
380 GOSUB 1020
390 K=K+1
400 READ# 1 ; N$
410 GOSUB 880
420 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 421 ELSE G
    OTO 390
421 DISP "Set# =",K
422 PRINT USING 330 ; "Start Dat
    e= ",D(1)," d   ",D(2),":",D(
    3);":",D(4)," h"
430 DISP "ENTER LAST RECORD"
431 DISP "ENTER END TIME"
432 GOSUB 1020
450 X0=0
460 GOSUB 960
480 K=K+1
490 READ# 1 ; N$
500 GOSUB 880
510 X0=0
520 GOSUB 960
530 IF X0<9 THEN GOTO 590
540 IF B<>0 THEN GOTO 770
550 DISP USING 560 ; D(1),"d",D(
    2),":",D(3),":",D(4),"  *...
    "
560 IMAGE 2D,K,3X,2Z,K,2Z,K,2Z,K
570 B=1
580 GOTO 770
590 IF B=0 THEN GOTO 620
600 DISP USING 560 ; D(1),"d",D(
    2),":",D(3),":",D(4),"
      *"
610 B=0
620 FOR N1=1 TO 32
630 IF X(N1)<T1 THEN GOTO 700
631 D8=X(N1)*X(N1)
640 H(N1)=H(N1)+D8
650 H(33)=H(33)+D8
700 NEXT N1
770 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 780 ELSE G
    OTO 480
780 PRINT USING 790 ; "End   Dat
    e= ",D(1)," d   ",D(2),":",D(
    3),":",D(4)," h"
790 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
791 PRINT "--------------------
    -----------"
800 PRINT USING 801 ; "Ch #    I
    ndex      %       Rank"
801 IMAGE 1/,K
820 R(33)=0
821 PRINT " "
822 FOR N1=1 TO 32
823 R(N1)=100*H(N1)/H(33)
824 R(33)=R(33)+R(N1)
825 NEXT N1
830 FOR N1=1 TO 33
831 IF N1=33 THEN PRINT "-------
    -------------------------"
832 H(N1)=H(N1)*1.3703
840 PRINT USING 850 ; N1,H(N1),R
    (N1)
850 IMAGE 3D,8D,8D
860 NEXT N1
870 END
880 REM *SUB READS DATE *
890 FOR N1=1 TO 4
900 X1=NUM(N$[N1])
910 L1=X1\16
920 L2=X1 MOD 16
930 D(N1)=10*L1+L2
940 NEXT N1
950 RETURN
960 REM *SUB READS DATA*
970 FOR N=1 TO 32
```

```
980 X(N)=NUM(N$[37-N])
990 IF X(N)>15 THEN X0=X0+1
1000 NEXT N
1010 RETURN
1020 REM * SUB INPUTS DATE *
1030 DISP "ENTER DATE"
1040 INPUT R1
1050 DISP "ENTER HOUR"
1060 INPUT R2
1070 DISP "ENTER MINUTE"
1080 INPUT R3
1090 RETURN
```

```
  9 REM   **********
 10 REM  ** HISTO **
 11 REM  **********
 20 REM THIS PROGRAM READS  DATA
 30 REM  & FORMS HISTOGRAMS  **
 40 OPTION BASE 1
 50 DIM N$[256],X(32),Q$[6],D(4)
    ,H(33,7),T(5)
 60 DISP "** HISTO **"
 70 DISP "ENTER TAPE NO."
 80 INPUT N7
 90 PRINT USING 91 ; "TAPE NO.",
    N7
 91 IMAGE K,5D
100 CAT
110 DISP "ENTER FILENAME"
120 INPUT Q$
130 PRINT Q$
140 ASSIGN# 1 TO Q$
150 FOR N7=1 TO 5
160 DISP "ENTER THRESHOLD % ."
170 INPUT T1
180 PRINT USING 190 ; "Threshold
    ",N7," =",T1,"%"
190 IMAGE K,2D,K,4D,K
200 T(N7)=T1/1.3703
210 NEXT N7
220 PRINT "--------------------
    -----------"
230 K=0 ! counts records
240 B=0 ! true when rt intef
250 FOR N1=1 TO 33
260 FOR N2=1 TO 7
270 H(N1,N2)=0
280 NEXT N2
290 NEXT N1
300 READ# 1 ; N$
310 GOSUB 880
320 DISP USING 330 ; "Tape Start
     Date=",D(1),"d   ",D(2),":"
    ,D(3),":",D(4)," h"
330 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
340 DISP "Start Here ?"
350 INPUT R$
360 IF R$="Y" THEN GOTO 421
370 DISP "ENTER START DATE/TIME"
380 GOSUB 1020
390 k=K+1
400 READ# 1 ; N$
410 GOSUB 880
420 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 421 ELSE G
    OTO 390
421 DISP "Set# =",K
422 PRINT USING 330 ; "Start Dat
    e= ",D(1)," d  ",D(2),":",D(
    3);":",D(4)," h"
430 DISP "ENTER LAST RECORD"
431 DISP "ENTER END TIME"
432 GOSUB 1020
```

```
450 X0=0
460 GOSUB 960
480 K=K+1
490 READ# 1 ; N$
500 GOSUB 880
510 X0=0
520 GOSUB 960
530 IF X0<9 THEN GOTO 590
540 IF B<>0 THEN GOTO 770
550 PRINT USING 560 ; D(1),"d",D
    (2),":",D(3),":",D(4),"  *..
    ."
560 IMAGE 2D,K,3X,2Z,K,2Z,K,2Z,K
570 B=1
580 GOTO 770
590 IF B=0 THEN GOTO 620
600 PRINT USING 560 ; D(1),"d",D
    (2),":",D(3),":",D(4),"
    ...*"
610 B=0
620 FOR N1=1 TO 32
630 N2=1
640 IF X(N1)<T(1) THEN GOTO 740
650 N2=2
660 IF X(N1)<T(2) THEN GOTO 740
670 N2=3
680 IF X(N1)<T(3) THEN GOTO 740
690 N2=4
700 IF X(N1)<T(4) THEN GOTO 740
710 N2=5
720 IF X(N1)<T(5) THEN GOTO 740
730 N2=6
740 H(N1,N2)=H(N1,N2)+1
750 H(33,N2)=H(33,N2)+1
760 NEXT N1
770 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 780 ELSE G
    OTO 480
780 PRINT USING 790 ; "End   Dat
    e= ",D(1)," d  ",D(2),":",D(
    3),":",D(4)," h"
790 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
791 PRINT "-------------------
    -----------"
800 PRINT USING 801 ; "HISTOGRAM
    "
801 IMAGE 1/,K
802 FOR N7=1 TO 5
803 T(N7)=T(N7)*1.3703
805 NEXT N7
810 PRINT USING 820 ; "Ch No. ",
    T(1),T(2),T(3),T(4),T(5)
820 IMAGE K,5D,5D,5D,4D,4D
821 PRINT " "
830 FOR N1=1 TO 33
831 IF N1=33 THEN PRINT "-------
    ------------------------"
840 PRINT USING 850 ; N1,H(N1,1)
    ,H(N1,2),H(N1,3),H(N1,4),H(N
    1,5),H(N1,6)
850 IMAGE 2D.   7D,6D,5D,4D,4D,4
    D
860 NEXT N1
870 END
880 REM *SUB READS DATE *
890 FOR N1=1 TO 4
900 X1=NUM(N$[N1])
910 L1=X1\16
920 L2=X1 MOD 16
930 D(N1)=10*L1+L2
940 NEXT N1
950 RETURN
960 REM *SUB READS DATA*
970 FOR N=1 TO 32
980 X(N)=NUM(N$[37-N])
990 IF X(N)>15 THEN X0=X0+1
1000 NEXT N
1010 RETURN
1020 REM * SUB INPUTS DATE *
1030 DISP "ENTER DATE"
1040 INPUT R1
1050 DISP "ENTER HOUR"
1060 INPUT R2
1070 DISP "ENTER MINUTE"
1080 INPUT R3
1090 RETURN
```

```
 10 REM  ** HALTS **
 20 REM THIS PROGRAM PRINTS DATA
 30 REM  ABOVE RECORDED LIMIT
 40 OPTION BASE 1
 50 DIM N$[256],X(32),Q$[6],D(4)
    ,P(4)
 60 DISP "** HALTS **"
 70 DISP "ENTER TAPE NO."
 80 INPUT N7
 90 PRINT "TAPE NO: ",N7
100 CAT
110 DISP "ENTER FILENAME"
120 INPUT Q$
130 PRINT Q$
140 ASSIGN# 1 TO Q$
150 DISP "ENTER THRESHOLD % :"
160 INPUT T1
170 DISP USING 180 ; "Threshold
    =",T1,"%"
180 IMAGE K,4D,K
190 DISP "-----------------------
    ----------"
200 T1=T1/1.3703
210 K=1
220 B=0
230 READ# 1 , N$
240 GOSUB 500
250 X0=0
260 GOSUB 580
270 GOTO 420
280 K=K+1
290 READ# 1 ; N$
300 GOSUB 500
310 X0=0
320 GOSUB 580
330 IF X0<9 THEN GOTO 390
340 IF B<>0 THEN GOTO 480
350 DISP USING 360 ; D(1),"d",D(
    2),":",D(3),":",D(4),"  *
    "
360 IMAGE 2D,K,5D,K,2D,K,2D,K
370 B=1
380 GOTO 480
390 IF B=0 THEN GOTO 420
400 DISP USING 360 ; D(1),"d",D(
    2),":",D(3),":",D(4),"
    ..*"
410 B=0
420 FOR N=1 TO 32
430 IF X(N)>T1 THEN 440 ELSE GOT
    O 470
440 X9=X(N)*1.3703
450 DISP USING 460 ; D(1),"d",D(
    2),":",D(3),":",D(4),"h  ch#
    ",N,X9,"%"
460 IMAGE 2D,K,3X,2Z,K, 2Z,K, 2Z
    ,K,DD,4D,K
470 NEXT N
480 GOTO 280
490 END
500 REM *SUB READS DATE *
510 FOR N1=1 TO 4
520 X1=NUM(N$[N1])
530 L1=X1\16
540 L2=X1 MOD 16
541 P(N1)=D(N1)
550 D(N1)=10*L1+L2
560 NEXT N1
561 P0=86400*(D(1)-P(1))+3600*(D
    (2)-P(2))+60*(D(3)-P(3))+D(4
    )-P(4)
562 IF P0<50 THEN GOTO 570
563 PRINT USING 564 ; "Stop  Dat
    e =",P(1),"d   ",P(2),":",P(
    3),":",P(4)," h"
564 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
565 PRINT USING 564 ; "Start Dat
    e =",D(1),"d   ",D(2),":",D(
    3),":",D(4)," h"
566 PRINT ""
570 RETURN
580 REM *SUB READS DATA*
590 FOR N=1 TO 32
600 X(N)=NUM(N$[37-N])
610 IF X(N)>15 THEN X0=X0+1
620 NEXT N
630 RETURN
```

```
  9 REM   **********
 10 REM  ** PEAK  **
 11 REM  **********
 20 REM THIS PROGRAM READS  DATA
 30 REM  & FORMS HISTOGRAMS  **
 40 OPTION BASE 1
 50 DIM N$[256],X(32),Q$[6],D(4)
    ,H(33,7),T(5),P(33)
 60 DISP "** PEAK  **"
 70 DISP "ENTER TAPE NO."
 80 INPUT N7
 90 PRINT USING 91 ; "TAPE NO.",
    N7
 91 IMAGE K,50
100 CAT
110 DISP "ENTER FILENAME"
120 INPUT Q$
130 PRINT Q$
140 ASSIGN# 1 TO Q$
220 PRINT "----------------------
    -----------"
230 K=0 ! counts records
240 B=0 ! true when rt intef
250 FOR N1=1 TO 33
251 P(N1)=0
260 FOR N2=1 TO 7
270 H(N1,N2)=0
280 NEXT N2
290 NEXT N1
300 READ# 1 ;,N$
310 GOSUB 880
320 DISP USING 330 ; "Tape Start
     Date=",D(1),"d   ",D(2),":"
    ,D(3),":",D(4)," h"
330 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
340 DISP "Start Here ?"
350 INPUT R$
360 IF R$="Y" THEN GOTO 421
370 DISP "ENTER START DATE/TIME"
380 GOSUB 1020
390 K=K+1
400 READ# 1 ; N$
410 GOSUB 880
420 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 421 ELSE G
    OTO 390
421 DISP "Set# =",K
422 PRINT USING 330 ; "Start Dat
    e= ",D(1)," d  ",D(2),":",D(
    3);":",D(4)," h"
430 DISP "ENTER LAST RECORD"
431 DISP "ENTER END TIME"
432 GOSUB 1020
450 X0=0
460 GOSUB 960
480 K=K+1
490 READ# 1 ; N$
500 GOSUB 880
510 X0=0
520 GOSUB 960
530 IF X0<9 THEN GOTO 590
540 IF B<>0 THEN GOTO 770
550 DISP USING 560 ; D(1),"d",D(
    2),":",D(3),":",D(4),"  *...
    "
560 IMAGE 2D,K,3X,2Z,K,2Z,K,2Z,K
570 B=1
580 GOTO 770
590 IF B=0 THEN GOTO 620
600 DISP USING 560 ; D(1),"d",D(
    2),":",D(3),":",D(4),"
    ..*"
610 B=0
620 FOR N1=1 TO 32
621 IF X(N1)>P(N1) THEN P(N1)=X(
    N1)
760 NEXT N1
770 IF R1=D(1) AND R2=D(2) AND R
    3<=D(3) THEN GOTO 780 ELSE G
    OTO 480
780 PRINT USING 790 ; "End   Dat
    e= ",D(1)," d  ",D(2),":",D(
    3),":",D(4)," h"
790 IMAGE K,2D,K,2Z,K,2Z,K,2Z,K
791 PRINT "----------------------
    -----------"
800 PRINT USING 801 ; "PEAKS"
801 IMAGE 1/,K
802 FOR N1=1 TO 32
803 P(N1)=P(N1)*1.3703
805 NEXT N1
810 PRINT "Ch No.          Max %"
821 PRINT " "
830 FOR N1=1 TO 32
831 IF N1=33 THEN PRINT "-------
    -------------------------"
840 PRINT USING 850 ; N1,P(N1)
850 IMAGE 2D,14D
851 IF N1=32 THEN PRINT "-------
    -------------------------"
860 NEXT N1
870 END
880 REM *SUB READS DATE *
890 FOR N1=1 TO 4
900 X1=NUM(N$[N1])
910 L1=X1\16
920 L2=X1 MOD 16
930 D(N1)=10*L1+L2
940 NEXT N1
950 RETURN
960 REM *SUB READS DATA*
970 FOR N=1 TO 32
980 X(N)=NUM(N$[37-N])
990 IF X(N)>15 THEN X0=X0+1
1000 NEXT N
1010 RETURN
1020 REM * SUB INPUTS DATE *
1030 DISP "ENTER DATE"
1040 INPUT R1
1050 DISP "ENTER HOUR"
1060 INPUT R2
1070 DISP "ENTER MINUTE"
1080 INPUT R3
1090 RETURN
```

APPENDIX 'B'

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TEST & EVALUATION
of
NAWS: Hull Stress Monitor
on
C.C.G.S. 'PIERRE RADISSON'
SUMMARY REPORT

Prepared for
Transportation Development Centre

TP 5317E

AUTHOR: A. Benjamin

DATE: March 5, 1984

Report No: 7042-R18

The contents of this report reflect the views of the authors and not necessarily the official view or policies of the Transportation Development Centre.

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17. Abstract

Navigation of ships in ice currently relies heavily on the experience and judgement of the navigators. The NAWS System initiates a new concept in ice navigation. The objective is to provide the navigator with sufficient information to aid him/her to navigate icebreakers nearer the ship's optimum design specifications.

NAWS is a response monitoring system that obtains primary information from an array of strain gauges installed at high risk areas on the forebody structure of the ship. The locations of the gauges are determined using structural analysis supplemented by practical experience.

The sensor signals are processed by microprocessors and impact magnitude and location information displayed on a front panel on the navigating bridge. A printer keeps a permanent record of higher stresses.

A test and evaluation program for the NAWS system was conducted in summer 1983 on the CCGS Pierre Radisson while on escort duty in the high Arctic. The performance of the system was assessed through a computer controlled data recording system, and through responses from questionnaires and interviews with the captain and navigation officers of the ship.

Seventeen data tapes were recorded and analysed. Analysis of the crew's imressions show that the system achieved its principal objectives and generated gratifying enthusiasm onboard the ship. Recommendations for future systems have been documented.

The NAWS system remains in continuous operation for both summer and winter ice operations on the CCGS Pierre Radisson, providing an instantaneous risk assessment for navigators.

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17. Résumé

La navigation dans une mer chargée de glaces fait largement appel à l'expérience et au jugement de l'officier navigateur. Le système NAWS modifie la navigation dans les glaces, en mettant à la disposition de cet officier l'information lui permettant d'exploiter le navire au plus près de ses capacités nominales.

Il s'agit d'un système réactionnel qui tire ses informations d'un réseau extensométrique réparti sur l'avant du navire, là où la coque est fortement exposée. L'emplacement des extensomètres a été déterminé par une analyse de la structure, complétée d'une bonne dose d'expérience dans le domaine considéré.

Les signaux émis par les extensomètres sont traités par des micro-ordinateurs qui les convertit en information exploitable et les transmet au pont. Une imprimante fait le relevé des impacts significatifs.

Un programme d'essai et d'évaluation du système a été conduit durant l'été de 1983 à bord du Pierre-Radisson, alors en mission d'escorte à l'intérieur du cercle polaire. Les performances ont été évaluées à l'aide d'un enregistreur contrôlé par ordinateur, et grâce à des sondages par voie de questionnaires et d'interviews personnels auprès du commandant et des officiers navigateurs.

Dix-sept rubans ont été enregistrés et analysés. D'après les réponses obtenues des intéressés, le système aurait atteint l'objectif fixé, ayant suscité un accueil enthousiaste parmi les utilisateurs. Le rapport formule des recommandations concernant les applications nouvelles possibles de ce système.

Le système, toujours en service à bord du Pierre-Radisson, facilite grandement la tâche des officiers navigateurs appelés à piloter ce navire dans les glaces, été comme hiver.

18. Mots-clés	19. Diffusion
Système réactionnel Détecteur des niveaux de contrainte Instrumentation Déglaçage Navires de cote arctique	Le CDT dispose d'un nombre limité d'exemplaires.

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We appreciate the assistance and patience of the Captain, Officers and Crew of the CCGS Pierre Radisson who lent their expertise in evaluating the NAWS System, and demonstrated professionalism in carrying out this task.

Special thanks are due to Dr. Ruth Heron of TDC who designed the Evaluation Questionnaire and assisted in the ergonomic aspects of the NAWS System design.

german & milne inc.

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1.0 INTRODUCTION

The navigation of ships in ice is a specialized skill demanding precise judgement on the part of the ship's navigating officers. Thus, in addition to regular sea navigation duties, officers in command of icebreaking ships must also familiarize themselves with these special techniques. The decisions involved in ice navigation include primarily the choice of the safest path through the ice and the selection of the maximum speed the ship may operate on this path without imposing undue stress (and the possibility of permanent damage) on any section of the ship's structure.

Safe navigation requires the ship's officers to identify the type, age and thickness of ice in the ship's vicinity and assess its corresponding strength. Based on experience, the officer then performs a mental correlation to determine the maximum speed the ship may operate without exceeding safe stress limits. The officer performs this estimation frequently, taking into account changes in the ice conditions. However, no direct evaluation of his/her judgement is possible, and so corrective action is usually based on indirect means such as ship's speed and structural vibrations.

However, the officer is not always able to obtain all information required in making this decision. Reasons vary from circumstances where poor visibility precludes proper identification of ice conditions, to practical considerations that require the navigating officer to perform other functions in addition to navigating the ship through ice.

Further, an officer experienced in navigation with a certain class and size of icebreaking ship is not always able to transfer this expertise to another ship of a different size and structural strength. Hence, the decision of selecting the safe operating speed is subjective and a matter of judgement on the part of the officer.

The optimum speed will be at or close to the highest speed the ship may operate without causing damage to any of the ship's structures or systems. While the more experienced officers will navigate close to this optimum speed, inevitably there will be some officers (although a small minority) who

exceed safe limits endangering the ship's safety, while there will be others (possibly a larger number) that will operate somewhat below safe limits, thereby, reducing the operational efficiency of the ship.

Hence, the need exists for a device that can provide a navigating officer an instantaneous evaluation of the ship's operating conditions. This direct feedback will enable the officer to take corrective action when necessary.

NAWS, a new hull stress monitoring instrument developed by German & Milne Inc. under contract to Transportation Development Centre initiates a new concept in ice navigation. Its objective is to aid officers navigating icebreaking ships to operate nearer the ship's optimum design conditions.

The concept is a response monitoring system that uses a microcomputer to analyze and interpret the severity of strains developed in the ship's hull structure during icebreaking. It provides information for the discretionary guidance of the navigating officers, just as other modern electronic navigation systems supplement the traditional celestial, pilotage, and dead-reckoning forms of navigation.

The system uses strain gauges to measure stresses. A micro-computer is used to translate the measurements into information which can be used by ship's officers. This information is displayed on a NAWS front panel on the Navigating Bridge.

The system obtains primary information from an array of sensors installed at strategic locations on the port and starboard bow areas of a ship. These sensors will provide signals proportional to the structural stresses caused by ice encounters. The system processes and interprets these signals into low, intermediate or high categories of stress levels.

The navigating officers are provided with a display of a sequence of lamp indicators that gives information on the general locations and intensity

1.0 INTRODUCTION (Cont'd)

of encounters as they occur. Display of an encounter at high levels is accompanied by an audio signal.

A permanent record of all intermediate and high stress levels is made by a printer. The printout indicates the magnitude of the maximum stress, its structural location and the time of its occurrence.

2.0 ERGONOMIC CONSIDERATIONS

In designing a response monitoring instrument, human factor considerations play as significant a role as any other. To the same extent, training of operating personnel is an integral part of the installation. A navigator will accept the instrument only if he understands the meaning of the information received and knows how to use it. He must also have confidence in its reliability and be able to incorporate monitoring of the new instrument easily into his task configuration.

In the case of the NAWS Instrument, it informs the navigator of the response of the hull to the momentary external conditions, but not on the ice conditions. The system merely "samples" the hull/ice interaction of the moment, yielding information not otherwise available to the navigation officer concerning the "typical" level of stresses created in the hull by the ice interaction. It can be appreciated then that NAWS is not seen as a substitute for experience and judgement on the part of the navigation officer but as a supplement to the information available to him to augment his decision making capabilities.

3.0 SYSTEM DESCRIPTION

The NAWS System is designed to function as a forebody strain monitoring system while engaged in ice operations. It will monitor the strains in the hull structure caused by ice impacts and relay this information to the Bridge. A front panel display on the Bridge indicates when the strains exceed prescribed safe operating values, and an audio alarm sounds when they

3.0 SYSTEM DESCRIPTION (Cont'd)

approach the yield point of the hull material. A permanent record of all unsafe strains is provided through a printer.

The System comprises of three units:

1. Strain Gauge Array
2. Remote Sensor Unit
3. Master Control

Strain Gauge Array

The effectiveness of the hull stress monitoring system depends primarily on the strain gauge configuration. Therefore, it is necessary that much attention be given to the selection of location of the strain gauges.

The placement of the strain gauges was based on FEM analyses of the hull structure in way of the Bow Thruster Compartment and the Heeling Tank, and on Full Scale Trials Results from tests conducted on the CCGS PIERRE RADISSON in the Arctic.

A total of thirty-two (32) gauges were installed on port and starboard bow back upto the shoulder, and just below the water-line.

Remote Sensor Unit

The Remote Sensor Unit obtains and processes basic data from the strain gauges. In turn, it transmits the information to the Master Control on the Navigating Bridge where it is displayed for the Navigator.

Each strain gauge forms one arm of a Wheatstone Bridge, the output of which is fed to a high gain low drift instrumentation amplifier. The amplifier outputs a signal in the range of 0 to 10 volts, which is proportional to a range of $\pm$2000 microstrains being registered by the strain gauge. The amplified signal is then filtered to remove line frequency noise.

3.0 SYSTEM DESCRIPTION (Cont'd)

A microcomputer controls all system functions. The use of a microcomputer as the controlling unit gives the system considerable versatility. It can vary the number of channels which are handled, and routinely carries out computations and processes information related to the strain gauge signals.

Master Control

A micro computer within the Master Control co-ordinates all activities of the NAWS System. The Master Control samples each Remote Sensor Unit sequentially and sends the information received for display at the appropriate section of the front panel. The Master Control will also list bad sensors on the printer for the information of the operator.

The front panel provides a convenient means for navigating officers to view stress levels. On the left of the display a schematic diagram of the bow section of the ship consisting of an array of lights graphically arranged on an outline of the cross-section of the hull at the waterline. The coloured lights are yellow and red to indicate when strain levels are intermediate and high respectively.

When all strain levels are normal, the green indicator confirms system operation. The green LED at the centre marked stress is a bar graph display to aid the officer to navigate efficiently nearer the design specifications of the ship.

Each ice impact encountered that exceeds 50% yield stress illuminates the corresponding LED for a period of four seconds, irrespective of the actual duration of the stress. This ensures the attention of the operator.

The printer on the lower right hand side makes a permanent record of all intermediate and high level stresses (yellow and red alarms). The printout indicates the percent of yield stress encountered, its structural location and the time it occurred.

3.0 SYSTEM DESCRIPTION (Cont'd)

Master Control (Cont'd)

Additional features on the front panel include switches for the audio alarm and printer when not required and to reset the operation. The keyboard and display aid test, maintenance and other operations including an option for display of time as shown in Figure 4.4. However, if not required, the display can be blanked.

4.0 INSTALLATION

Installation of components of the pre-production model of the NAWS System was carried out in Quebec City between April and August 1983.

Based on the analysis of the ship's hull structure, the number and optimum locations for the mounting of the strain gauges were first determined. An array of thirty-two (32) strain gauges was considered to be sufficient to provide the required coverage for the NAWS System.

5.0 TRAINING

NAWS was designed such that the navigator can easily relate the information he gets from it to the overall picture. On the other hand, it is necessary to make him aware of the limitations of the system, otherwise he might be lulled into a false sense of security believing the instrument will detect all potential ice hazards. His alertness would then be reduced, and situations not sensed by the instruments may take him by surprise.

Hence, based on our experience, the NAWS Instrument was carefully designed to provide information adjusted to the navigator's ability to interpret and act correctly. Further, in order that he derive maximum benefit from the system, training formed an integral part of the installation of the system.

6.0 TEST AND EVALUATION

Schedule

A special test and evaluation program was conducted on the CCGS 'PIERRE RADISSON' in summer 1983, while on escort duty in the Arctic. During this period a German & Milne engineer was on board to monitor the system and assist the operators in use and interpretation of information provided by the system. Further the response of the crew to the system with their comments was solicited by the engineer through personal interviews and questionnaires.

The test and evaluation program took place between 18th August and 10th September 1983. Although a total of 18 days was spent on board ship, due to scheduling of the escort duty on the two voyages not all the time was spent in ice. In fact, during the period between the 25th of August 1983 and 4th September 1983, no significant ice was encountered.

Operations

Ice conditions were sparse and hence a sufficient number of different ice conditions necessary to provide a data base for a complete data analysis was not possible. As the 'PIERRE RADISSON' was providing escort service, it was not possible to deviate from the ship's course in the interest of safety for the cargo ship.

However, as the purpose of the test and evaluation was primarily to evaluate the ergonomic efficiency of the display as a navigating tool, the recorded data merely serves to backup the comments obtained.

Response from Crew

The System generated gratifying enthusiasm from the Captain and officers on the ship, and remains installed and in continuous use. In general, the system achieved its principal objectives, functioning as a tool to help navigating officers monitor hull stress in ice.

6.0 TEST AND EVALUATION (Cont'd)

Response from Crew (Cont'd)

Comments on the system performance were obtained through personal interviews and a questionnaire specially designed for this purpose.

Interviews

Some of the major comments of the navigators obtained in interviews are summarized below:

1. As a navigating device the location of the NAWS display aft on the navigation console did not provide the navigator with instantaneous information on the stresses developed in the ship's hull as he spends the large majority of his time near the telegraph.

   The device was located at this location because being unproven, the operators felt an evaluation of the usefulness and reliability of the system was called for. Further, location of the system aft on the bridge allowed the German & Milne operator continuous access to the system without interfering with the regular navigation duties of the ship's crew.

   In this position, use of the system was limited to calling for the information by the navigator, from a NAWS observer. However, due to many aspects of the information provided (magnitude, colour code, location, etc.) not all information could be provided verbally. Many officers have indicated that having observed the device, they felt the usefulness of NAWS would be increased if located nearer the telegraph. Here, the device would give a direct instantaneous feedback of the ship's response to the navigator, thus helping in evaluating his decisions and consequently his ability to take corrective action when necessary.

2. Display of the magnitude of the stresses has been colour coded into three levels:

Green:	Low level	0 to 50% of yield stress
Yellow:	Intermediate level	50 to 80% of yeld stress
Red:	High level	80% and above of yield stress

While stress indications at low (below 50%) levels are sub-divided into eight distinct steps (approximately 6% per step), no sub-divisions were used in the intermediate and high stress level indications (above 50%). Hence, when an intermediate or high stress level is observed, the navigator is not able to ascertain from the display whether the observed values are at the upper or lower end of the scale. It was suggested, therefore, that the principle used to display low stress levels be extended for use in displaying intermediate and high stress levels.

3. Indication of intermediate and high stress levels were retained on the display for four seconds. The general feeling here was that this gave insufficient time for the navigator to assimilate the information and make the next decision without having to memorize the information. A display retention time of ten seconds was believed to be more appropriate.

4. As a navigating device forward, it was recommended that dimmer and volume controls be made available for the lights and audio alarm respectively, so as to be kept below the visual and audio annoyance level.

The new display format as envisaged by the Captain of the ship has incorporated the recommendations received during evaluation of the system. Consultations with the TDC Ergonomist confirms that from a human factors consideration the new format will be a more effective method of displaying the information.

6.0 TEST AND EVALUATION (Cont'd)

Questionnaires

A questionnaire was scientifically designed as a means of obtaining the responses of the crew on all aspects of the system. In some aspects, the use of a questionnaire is better than an interview because all issues are addressed. It is thus possible to obtain the operators views on minor details, not always possible in an interview.

The questionnaire was designed by a Senior Ergonomist at TDC. Responses from the crew to the questionnaires were fed back to the ergonomist who analysed the information and prepared a report summarising their views. It is believed that the professional comments of the ergonomist enhances the objectivity of the evaluation.

7.0 ANALYSES

Objectives

A special data recording system was used to store on tape data being received and displayed by the NAWS System. The purpose of the Data Recording System was to review the data in light of comments on the system received from the crew and attempt simple correlations between the two.

One major outcome is determination of effectiveness of strain gauge array. The final configuration of the strain gauge array was arrived at using both a hull structural analysis and the available casualty analysis for the CCGS 'PIERRE RADISSON'. Using statistical analysis of recorded data (histograms, etc.), an evaluation of the configuration and verification of activity levels of individual gauges is carried out to determine critical locations.

Further, software capability has been developed for a simulation of the NAWS front panel in various ice conditions during the voyage. This will enable non-operating personnel such as Canadian Coast Guard, TDC and members of the commercial marine industry to evaluate the front panel in different ice conditions. It can also be used as a basis for training navigating officers in the use of the NAWS System.

7.0 ANALYSES (Cont'd)

Objectives (Cont'd)

In most cases, ice conditions were not consistent, hence no conclusive relationship could be established between the ship's operating parameters (ice cover/thickness, ship speed/mode, etc.). In fact, it was not the intent of the recording operation to achieve this, but rather to create a data base to determine the extent of strain gauge activity and consequently the NAWS front panel. This information is then correlated with the operator's comments to evaluate the ergonomic design.

Equipment

The HP-85 computer system was used as a data recording system for the duration of the evaluation program. It combines an alphanumeric keyboard, CRT screen, thermal printer, tape drive unit, user read/write memory, and a ROM operating system in one portable package, hence allowing ease of transportation on and off the ship.

A special interface was designed to handle data transfer between the NAWS Master Unit and the HP-85. The interface enabled the NAWS Instrument to communicate with other equipment with the syntax and formats of the ANSI/IEEE 488 standard. Handshake lines were used to coordinate the transfer of data over the data bus to ensure integrity of the data. The data transfer is asynchronous and the transfer rate automatically adjusts to the speed of the sender and receiver, ensuring that both devices are ready for this operation.

Results

A total of 17 tapes were recorded on the two voyages to Eureka NWT during which a total of 131 hours of data were recorded on these two voyages. Ice conditions varied considerably during these two voyages. All seventeen tapes were analyzed and histograms obtained for each tape.

7.0 ANALYSES (Cont'd)

Results (Cont'd)

Stress values exceeding 50% yield stress (corresponding to yellow and red alarms on the system) are very infrequent. Thus, during the major portion of the time, the display of the NAWS System operates in the green region (low stress levels). The low number of alarms simplifies use of the system by the navigator. Frequent yellow and red alarms would lead to desensititization of the navigators to the system and also require interpretation of the display. The infrequency of yellow and red lights ensures that when they do occur they will receive the attention of the navigator. The selection of the intermediate stress level at 50% yield stress, and high stress level at 80% yield stress will hence be continued in all NAWS equipment.

It was observed that higher values of stress were experienced in the ramming mode than in the continuous mode. This is to be expected since for a particular ice environment, icebreakers resort to the ramming mode only when unable to proceed in the continuous mode. Discussion on information collected and results obtained in each of the two modes follow.

Gauge Activity Level

Based on the above discussions and other data recorded, a Gauge Activity Table was compiled for the ramming and continuous modes.

It indicates that the choice of the strain gauge array was an adroit combination of two arrays designed to detect impacts in the ramming and continuous mode.

8.0 FUTURE APPLICATIONS

While the primary function of the NAWS System is to monitor ice impacts on the ship's bow, the system can also be used to monitor other critical stresses caused by ice.

8.0 FUTURE APPLICATIONS (Cont'd)

Ships navigating in ice fields experience high lateral pressure that may on occasion reach significant proportions. This situation is also encountered by ships frozen-in during the winter months. In both these cases, stress sensors installed amidships will monitor and warn the bridge of excessive field ice pressures.

In addition, during ice breaking the propeller and rudder equipment are also susceptible to damage by ice fragments. These too can be monitored by the system.

Further, the system function can be extended for use in examining structural stress from encounters other than ice, which are often of equal concern.

A potential application here is slamming on ships where hydrodynamic loadings in heavy seas can cause damage to the scantlings and other areas of the hull girder. The impulsive loadings can cause whipping or springing of the hull, and vibrations at much higher frequencies than those usually caused by the passage of the waves. The stress cycling may cause fatigue problems, particularly at points of high stress concentrations at the rapid loading rates and are more likely to cause cracking than are slowly varying hull bending stress. The NAWS System can be modified to monitor effects of slamming and fatigue on ship's structures.

Finally, the instrument is not limited to the use of strain gauges alone as the sensing element. Transducers such as accelerometers and thermistors may also be used in conjunction with the NAWS instrument to monitor forces and temperatures.